Essays on International Trade and Economic Geography

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Veröffentlichung als Dissertation in der Wirtschaftswissenschaftlichen Fakultät der Technischen Universität Dortmund

Dortmund, 2023

Acknowledgments

I am deeply grateful to the numerous people who have supported me in pursuing my PhD.

First and foremost, I would like to express my sincere gratitude to my supervisor, Jens Wrona, for his invaluable guidance, support, and encouragement throughout my PhD journey. I am also profoundly grateful to Philip Jung, Sanne Kruse-Becher and all the principal investigators in the research training group (RTG) – "Regional Disparities and Economic Policy", for providing me with the resources and opportunities to pursue my research.

I would like to extend my heartfelt appreciation to my colleagues, Lu, Nina, Johannes, and Malte, for their insightful discussions, feedback, and camaraderie. Your contributions have made my work more enjoyable and helped me grow as an economist.

I am immensely grateful to my family members for their unwavering support, encouragement, and understanding. In particular, I would like to thank my cousin Giorgi, who has been a constant source of inspiration and indispensable advice throughout my PhD journey.

Herewith, I would like to express my sincere gratitude to German taxpayers who financed my Master's and PhD studies. Your financial support has been instrumental in helping me achieve my academic goals, and without it, I would not be where I stand today. I am truly grateful for your generosity.

Lastly, I dedicate this dissertation to my wife, Maro, who has been my pillar of strength and constant support. Despite your busy schedule, you always found time to listen to me and provide me with the love and encouragement that kept me going.

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Introduction

This dissertation consists of three essays in the field of international trade and economic geography.

The first essay develops an international trade model with firms that differ in their productivities and compete under monopolistic competition in the goods market and under monopsonistic competition in the labour market. The key feature of the model is that firms are competing for workers not only by offering higher wages but also by investing into the quality of their workplace amenities. Due to the monopsonistically competitive labour markets, firms face upward labour supply curve. As a result, if a firm decides to hire more workers, it has to pay higher wages and offer better workplace amenities to compensate the marginal worker for the utility loss caused by giving up alternative employment opportunities. This essay shows that the most productive firms, which select into exporting, pay not only an exporter-wage-premium but also offer a more attractive non-monetary compensation than comparable non-exporting firms. By allowing firms to endogenously adjust their workplace quality, a new non-pecuniary welfare gain from globalisation is established. Therefore, welfare predictions, which exclusively focus on real income metrics, might underestimate the gains from globalisation. A quantitative exercise in this essay confirms theoretical findings. By computing a sufficient statistic for the gains from trade, that can be readily quantified based on observable data, this essay simulates that the gains from trade are systematically overlooked if the endogenous adjustment of the workplace quality in response to a globalisation shock is not taken into account.

By introducing a new margin for firms to optimally adjust to a globalisation shock, this essay contributes to sizeable literature studying the welfare gains from globalisation[1] in the presence of frictional labour markets[2]. Particularly relevant work is the paper by Egger et al. (2022), which studies the differential effects of international trade and offshoring on welfare in the presence of monopsonistically competitive labour markets. This essay can be regarded as the extension of Egger et al.'s (2022) paper by showing that firms not only differ in their optimal wage-setting policies but also in terms of the average quality of workplace amenities. The gains from trade, therefore, not only materialise in terms of a higher purchasing power but also in terms of a higher average workplace quality[3].

The second essay, co-authored with Lu Wei, studies to what extent trade liberalization affects regional production fragmentation. In particular, we derive empirical indicators measuring the European Union (EU) regions'[4] engagement in cross-border production chains. Our analysis relies on input-output tables from the EU, which enable us to calculate the gross and value-added trade for each EU NUTS2 region between 2000 and 2010. The essay's primary goal is to investigate how the regional gross and value-added exports respond to the reduction of bilateral tariff rates, as any divergence between these two sheds light on regional production fragmentation. By exploiting a unique trade policy variation associated with the 2004 EU enlargement, we show that regions facing larger tariff cuts have significantly increased trade along the value chain. Our identification strategy is based on the assumption that trade policy changes are heterogeneous across sectors and that sectoral economic activity is nonuniformly distributed across EU regions. As a result, equipped with the gravity-style specification and using the well-established shift-share analysis, we are able to capture the differential effect of tariff reductions on regions' participation in production sharing within the EU. More precisely, our estimates suggest that a one percentage point decrease in tariff rates, associated with the 2004 EU enlargement, decreases the regional value added to gross exports (RVAX) ratio by 3.2%. A decline in the RVAX ratio indicates that regions facing larger tariff cuts due to the enlargement increased their engagement in

[1]see Costinot and Rodríguez-Clare (2014), for a literature review.

[2]Most of the studies assume either rent sharing mechanism (Amiti and Davis, 2012; Egger and Kreickemeier, 2012; Helpman et al., 2017) or assortative matching between the firms and workers (Sampson, 2014; Grossman et al., 2017)

[3]Note that this essay has already been published in Ruhr Economic Papers (Abashishvili, 2023).

[4]In this chapter, regions are defined at NUTS2 level

cross-border production chains relative to the other regions.

The second essay is related to the recent empirical research studying the emergence of global value chains (GVCs) (see Antràs and Chor, 2022, for a detailed overview). From the measuring point of view, literature usually uses the value-added content of trade to capture the countries' participation in GVCs (Johnson and Noguera, 2012; Koopman et al., 2014; Borin and Mancini, 2019). Empirical studies also document that changes in trade frictions play a major role in raising the GVCs (Johnson and Noguera, 2017). However, most of the papers in the field usually treat countries as a point in space, neglecting the regional heterogeneity within the countries. In this essay, we fill this gap by focusing on the EU regions' participation in production sharing and their response to trade liberalization followed by the 2004 EU enlargement.

The first and second essays of the PhD thesis cover the topics concerning globalisation and trade liberalization. The subsequent essay shifts its emphasis towards the field of economic geography. In particular, the third essay tests the prediction of Christaller's (1933) central place property (CPP), according to which a smaller city can always be found between two larger cities. In order to empirically validate the CPP, this essay starts by collecting geospatial data on islands where economic activity is only distributed along the coastal region due to their volcanic geography. By constructing such a type of data, the observed spatial distribution of economic activity can be matched to the key theoretical assumption of the CCP, which posits that all economic activity must take place either on a line or on a circle. The final data set consisted of the geolocation of 84 oval-shaped islands complemented by the Open Street Map's (OSM) publicly available buildings and road network data. Following the recent literature that delineates cities[5], an unsupervised machine learning algorithm is used to detect urban areas on each island. This essay shows that, on average, 70% of the size distribution of the neighbouring urban areas in the data follows the spatial pattern predicted by the CPP. Moreover, the observed size distribution of the urban areas is compared to its counterfactual counterpart, which is obtained by randomizing cities' locations on each island. A simple one-tailed statistical test reveals that the observed and counterfactual size distributions differ significantly. Hence, the results obtained in this essay

[5] See Bellefon et al. (2021), and Arribas-Bel et al. (2021) who use geolocated buildings data to delineate urban areas in France and Spain.

suggest that the observed spatial distribution of urban areas in the data is not due to chance but instead might be driven by the economic forces usually micro-founded in the CPP literature.

The third essay makes several contributions. Firstly, it provides a novel and publicly accessible geospatial database of islands where economic activity is distributed along the coastline. The database can be used in further studies in order to empirically validate the theoretical findings of the spatial competition models, which usually assume a simplified geographical structure. Secondly, this essay contributes to the theoretical literature, which explores Christaller's (1933) central place theory. Fujita et al. (1999), Tabuchi and Thisse (2011), and Hsu (2012) provide the theoretical underpinnings for the emergence of the hierarchical urban system in the spirit of Christaller (1933). A highly relevant study for this essay is a paper by Hsu (2012), in which the author provides the microeconomic foundations of the central place property. The findings presented in this dissertation can be regarded as the empirical evidence supporting Hsu's (2012) theoretical results. Thirdly, this essay contributes to the growing literature which delineates the urban areas in developing countries (see Duranton, 2015, for a detailed overview). In particular, it is demonstrated that using the OSM data, urban areas can be detected on remote territories where the auxiliary geographies, such as commuting flows or satellite imagery, are unavailable.

The rest of the PhD thesis is structured as follows: Chapter 1 presents the first essay titled "Exporting and endogenous workplace amenities under monopsonistic competition." Chapter 2 discusses the second essay, "Trade liberalization and regional production fragmentation." The third essay, "Empirics of the central place property using islands data," is presented in Chapter 3. Finally, the concluding chapter summarises the findings of this dissertation.

CHAPTER 1

Exporting and endogenous workplace amenities under monopsonistic competition

1.1 Publication details

Paper I (Chapter 1):

Exporting and endogenous workplace amenities under monopsonistic competition

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Abstract:

This chapter introduces endogenous workplace quality choice into an international trade model with a monopsonistically competitive labour market, in which firms compete for potential employees by offering them a combination of monetary and non-monetary benefits. To attract the workers required to produce for the foreign market in addition to the domestic market, exporting firms have to offer more attractive compensation to their employees than comparable non-exporting firms, which is why they are not only paying higher wages but also offering better workplace amenities. The gains from trade, therefore, not only materialise in terms of a higher purchasing power but also in terms of a higher average workplace quality. Therefore, welfare predictions, which exclusively focus on real income metrics, might underestimate the gains from globalisation

Publication details:

Ruhr Economic Papers (No. 1008); 2023.
doi:10.4419/96973174

1.2 Introduction

This chapter extends the international trade model of Egger et al. (2022), which features heterogeneous firms operating in a monopsonistically competitive labour market by allowing firms to endogenously choose their average workplace quality. Workers perceive firms as horizontally differentiated employers, which results in a firm-specific labour supply function that is upward-sloping in the monetary (wages) and non-monetary (workplace quality) compensations that firms grant their workers in exchange for their labour supply. As a consequence, it is optimal for firms to compete for workers not only in terms of wages but also in terms of workplace quality, which results in wage and workplace quality premia for more productive and, therefore – ceteris paribus – larger firms.

In the model, firms are different in terms of their productivity à la Melitz (2003), and not all the firms active in the domestic market are productive enough to be engaged in global trade through exporting. In the labour market, firms hire workers to produce intermediate inputs. As a part of the optimal hiring strategy, firms thereby have to choose the average quality of their workplace amenities, which are subject to a fixed-cost investment. The crude summary of this chapter is that compared to non-exporters, exporters not only pay higher wages but also offer higher workplace amenities to their workers. The underlying mechanism can be structured as follows: if a firm decides to export, it has to hire more domestic workers, which translates into increased wages and workplace quality, as the firm must compensate the marginal worker for the utility loss caused by giving up alternative employment opportunities.

Monopsonistic competition in the labour market is modelled in the spirit of Egger et al. (2022), where the firms face an upward labour supply curve, which depends positively on the wages firms have to pay to their employees, as well as on the average quality of firm-specific workplace amenities. Using the well-established discrete choice framework as in McFadden (1976) and Thisse and Toulemonde (2010), the firm-specific upward labour supply curve is derived by assuming that workers' preferences are independently and identically distributed over the continuum of firms. As a result, compared to Egger et al. (2022), in this model, when firms require to hire more workers, they can pay not only higher wages to their employees but also offer better workplace quality.

By allowing firms to endogenously adjust the quality of their workplace amenities, a new adjustment margin for the gains from globalisation is established, which materializes not only through the goods market but also through the labour market. Non-pecuniary welfare gains in the labour market thereby emerge for two reasons: Either there is an increase in average workplace quality across all firms, which benefits workers because workplace quality directly enters in their utility, or there is an increase in the number of firms that are active in the labour market, which is good for workers that prefer to choose among more options in the labour market. The exporting activity is associated with non-pecuniary welfare gains – although for very different reasons: As in Melitz (2003), the trade in intermediate inputs is associated with a reallocation of workers from less to more productive firms, which due to their larger size not only pay higher wages but also offer on average better amenities to their employees. At the same time, the exit of low-productivity non-exporting firms results in fewer options in the labour market, which – ceteris paribus – is associated with lower welfare. Solving for workplace quality-based welfare gains from exporting in general equilibrium, this chapter demonstrates that the welfare increase due to consumption and an average better workplace quality dominates the welfare loss due to a reduction in the number of firms that operate in the labour market.

Having established that there are aggregate welfare gains from globalisation, it is essential to note that these gains not only arise through the usual increase in overall consumption but also through the increase of non-pecuniary welfare. A quantification of the gains from globalisation that only accounts for the real-income metrics may therefore underestimate the total gains from trade. Using the World Input-Output table, constructed by Timmer et al. (2015), this chapter computes the sufficient statistic for the gains from trade. Obtained empirical results strengthen the theoretical findings – the welfare gains from globalisation are systematically underestimated if the endogenous adjustment in workplace quality in response to a globalisation shock is not taken into account.

By introducing a new margin for firms to optimally adjust to a globalisation shock, this chapter contributes to sizeable literature studying the welfare gains from international trade (see Costinot and Rodríguez-Clare, 2014, for an overview). Arkolakis et al. (2012) (henceforth - ACR) derive the welfare gains from trade using two sufficient statistics: the domestic expenditure share and the elasticity of imports with respect to the international trade costs. This chapter contributes to this literature by incorporating preferences for non-monetary compensations in the labour market when evaluating the aggregate welfare gains from trade.

This chapter is also related to the recent research studying the effects of international trade on the wage premium. The majority of existing works in the literature assumes either rent sharing mechanism (Amiti and Davis, 2012; Helpman et al., 2017; Egger and Kreickemeier, 2012), or assortative matching between firms and workers (Sampson, 2014; Grossman et al., 2017). In Egger et al. (2022), firm-specific wage effects of exporting and offshoring are derived under monopsonistic competition in the labour market. This chapter extends the Egger et al.'s (2022) work by showing that firms differ not only in their optimal wage-setting policies but also in terms of the average quality of the workplace that they offer to their employees.

The assumption that workers react on non-wage job attributes is already well-grounded in the applied labour economics literature (Eriksson and Kristensen, 2014; Mas and Pallais, 2017; Wiswall and Zafar, 2018). Despite the differences in their identification strategies, all of these papers provide evidence that workers value non-wage job characteristics, such as alternative working arrangements and scheduling flexibility. The purpose of such studies is to estimate the workers' valuation of particular firm-level amenities. The goal of this chapter is rather different. This chapter does not attempt to evaluate the explicit bundle of non-wage job characteristics to which workers could potentially react. Instead, the objective of this chapter is to show that, whatever the valuation of workplace amenities may be, trade liberalization always delivers non-pecuniary welfare gains.

The rest of this chapter is structured as follows. In section 2, the article discusses the firms' optimal behaviour in a partial equilibrium framework. Section 3 characterises the general equilibrium and provides the microeconomic foundations of the labour supply. Section 4 discusses the effects of exporting on aggregate welfare. Section 5 provides the quantitative relevance of the model, and the last section summarizes the main findings.

1.3 Theory

The world economy consists of two countries, each with two sectors. In the upstream sector, labour is used to produce horizontally differentiated intermediate inputs under monopolistic competition in the goods market and monopsonistic competition in the labour market. In the downstream sector, these intermediate inputs are then used to produce a freely tradable numéraire good under perfect competition. Upon paying the fixed entry costs $f_e > 0$ intermediate input producer ω draws constant productivity $\varphi(\omega)$ from the Pareto distribution $G(\varphi) = 1 - \varphi^{-g}$ and decides whether to enter the domestic market at fixed costs $f_d > 0$. Exporting is associated with variable trade costs $\tau \geq 1$ and foreign market entry costs $f_x > 0$. All fixed costs are paid in units of the numéraire.

1.3.1 Optimal firm behaviour

Firms compete under monopolistic competition in the goods market and under monopsonistic competition in the labour market. In the goods market, an isoelastic demand function $x(\omega) = A_G p(\omega)^{-\sigma}$ with a constant price elasticity of demand $\sigma > 1$ is assumed. The demand shifter A_G thereby captures all general equilibrium effects that operate through the goods market. Labour supply to the firm is given by $h(\omega) = A_L[a(\omega)^{\alpha} w(\omega)^{1-\alpha}]^{\frac{1-\theta}{\theta}}$, which is positively associated with the wage $w(\omega)$, that firm ω has to offer, and on the average workplace quality $a(\omega)$, that workers can expect when deciding in favour of the firm ω. The parameter $\theta \in [0, 1]$ is a constant that is inversely related to the labour supply elasticity with respect to the compensation bundle $a(\omega)^{\alpha} w(\omega)^{1-\alpha}$. The importance of workplace quality versus wages in the compensation of workers thereby is governed by $\alpha \in [0, 1)$. The supply shifter $A_L > 0$ captures all general equilibrium effects that operate through the labour market.[1]

Firms can optimally choose the average workplace quality $a(\omega)$ that they would like to offer to their workers. The workplace quality $a(\omega)$ thereby is associated with fixed costs $a(\omega)^{\delta}/\delta > 0$, that depend on the cost parameter $\delta > \alpha(1 - \theta)/\theta$. Binary indicator $I(\omega)$ differentiates exporters (with $I(\omega) = 1$)

[1] Detailed microfoundations for the firm-level goods demand and labour supply are derived in Section 3

from non-exporters (with $I(\omega) = 0$), while an asterisk marks foreign variables. The firm's profit maximization problem can be written as

$$\max_{x(\omega),x^*(\omega),l(\omega),a(\omega),I(\omega)} \quad p(\omega)x(\omega) + \frac{I(\omega)}{\tau}p^*(\omega)x^*(\omega) - w(\omega)l(\omega) - \frac{a(\omega)^\delta}{\delta} - I(\omega)f_x - f_d - f_m, \tag{1.1}$$

which is solved subject to the *(i)* the labour market clearing conditions, which are given by $l(\omega) = h(\omega) = A_L[a(\omega)^\alpha w(\omega)^{1-\alpha}]^{\frac{1-\theta}{\theta}}$; *(ii)* the goods market clearing conditions given by $x(\omega) = A_G p(\omega)^{-\sigma}$ and $x^*(\omega)/\tau = A_G^* p^*(\omega)^{-\sigma}$ in the case of exporting; and *(iii)* the constraint that the firm's domestic and exporting market output must be equal to its total production, $x(\omega)+I(\omega)x^*(\omega) = y(\omega)$.

The optimal allocation of aggregate output $y(\omega)$ across markets is given by $x(\omega) = y(\omega)$ for non-exporters and $x^*(\omega) = (A_G^*/A_G)\tau^{1-\sigma}x(\omega)$ as well as $x(\omega) = y(\omega)[1 + (A_G^*/A_G)\tau^{1-\sigma}]^{-1}$ for exporters. Firm-level revenues, therefore, are given by

$$r(\omega) \equiv p(\omega)x(\omega) + \frac{I(\omega)}{\tau}p^*(\omega)x^*(\omega) = A_G^{\frac{1}{\sigma}}\Big[\kappa(\omega)y(\omega)\Big]^{\frac{\sigma-1}{\sigma}} \quad \text{with } \kappa(\omega) \equiv \left(1 + \frac{A_G^*}{A_G}\tau^{1-\sigma}\right)^{\frac{I(\omega)}{\sigma-1}}. \tag{1.2}$$

Similar to Egger et al. (2022), the multiplier $\kappa(\omega)$ in Eq. (1.2) captures the relative size difference between overall and domestic markets and equals to one for non-exporters while $\kappa \equiv [1 + (A_G^*/A_G)\tau^{1-\sigma}]^{\frac{1}{\sigma-1}} > 1$ for exporters.

The optimal average workplace quality $a(\omega)$ has to minimize

$$\min_{a(\omega)} \quad w(\omega)l(\omega) + \frac{a(\omega)^\delta}{\delta}. \tag{1.3}$$

The wage bill $w(\omega)l(\omega)$ in Eq. (1.3) can be replaced by $w(\omega)l(\omega) = a(\omega)^{-\alpha/(1-\alpha)}$ $[y(\omega)/\varphi(\omega)]^{1/(1-\beta)}A_L^{-\beta/(1-\beta)}$ with $\beta \equiv \theta/[(1-\alpha)(1-\theta)+\theta] \in (\alpha/[\alpha+(1-\alpha)\delta], 1]$, which is obtained by equating firm ω's labour demand $l(\omega) = y(\omega)/\varphi(\omega)$ with the labour supply $h(\omega) = A_L[a(\omega)^\alpha w(\omega)^{1-\alpha}]^{\frac{1-\theta}{\theta}}$. The cost-minimizing average workplace quality can therefore be determined as

$$a(\omega) = \left\{ \frac{\alpha}{1-\alpha} \left[\frac{y(\omega)}{\varphi(\omega)} \right]^{\frac{1}{1-\beta}} A_L^{-\frac{\beta}{1-\beta}} \right\}^{\frac{1-\beta}{1-\gamma}\frac{1}{\delta}}, \tag{1.4}$$

in which $\gamma \equiv \{\beta[\alpha + (1-\alpha)\delta] - \alpha\}/(1-\alpha)\delta \in (0,1]$ with $\gamma \leq \beta$. Substituting $a(\omega)$ from Eq. (1.4) back into the objective function from Eq. (1.3) then yields the minimum cost function

$$c(\omega) = \frac{1-\gamma}{1-\beta} \left(\frac{1-\alpha}{\alpha} \right)^{\frac{\beta-\gamma}{1-\gamma}} \left[\frac{y(\omega)}{\varphi(\omega)} \right]^{\frac{1}{1-\gamma}} A_L^{-\frac{\beta}{1-\gamma}}. \tag{1.5}$$

To derive the profit-maximizing output level

$$y(\omega) = \left[CAA_G^{-\frac{1-\rho}{\sigma-1}} \kappa(\omega)^\rho \varphi(\omega) \right]^{\frac{1}{1-\rho}} \quad \text{with} \quad A \equiv A_G^{\frac{1}{\sigma-1}} A_L^\beta \tag{1.6}$$

the difference $\pi(\omega) \equiv r(\omega) - c(\omega)$ between revenues $r(\omega)$ in Eq. (1.2) and costs $c(\omega)$ in Eq. (1.5) is maximised with respect to $y(\omega)$.[2] The respective first-order condition $dr(\omega)/dy(\omega) = dc(\omega)/dy(\omega)$ can be easily solved for $y(\omega)$ by linking marginal revenue and marginal cost to average revenue and average variable cost

$$\frac{r(\omega)}{y(\omega)} = \frac{\sigma}{\sigma-1} \frac{dr(\omega)}{dy(\omega)} \qquad \text{and} \qquad \frac{c(\omega)}{y(\omega)} = (1-\gamma) \frac{dc(\omega)}{dy(\omega)}$$

As in Egger et al. (2022), monopolistic competition in the goods market results in a constant price markup $\sigma/(\sigma-1) > 1$ over marginal revenue. Moreover, the average variable and marginal costs are linked to each other by the markdown $1-\gamma < 1$, which mirrors the firm's monopsony power in the labour market. Due to the fact that labour supply and product demand are iso-elastic, the product of the wage markdown and price markup $1/\rho$ with $\rho \equiv (1-\gamma)(\sigma-1)/\sigma \in [0,1]$ is independent of the firm's output level.

Evaluating $r(\omega)$ from Eq. (1.2) at the optimal output level $y(\omega)$ from Eq. (1.6) allows us to solve for firm-level revenues

$$r(\omega) = [CA\kappa(\omega)\varphi(\omega)]^\xi. \tag{1.7}$$

[2] The constant $C \equiv [(1-\alpha)/\alpha]^{\beta-\gamma} [\rho(1-\beta)/(1-\gamma)]^{1-\gamma} > 0$ summarizes exogeneous parameters.

From Eq. (1.7), $\xi \equiv (\sigma-1)/\sigma(1-\rho) = (\sigma-1)/[1+\gamma(\sigma-1)] \in [(\sigma-1)/\sigma, \sigma-1]$ corresponds to the elasticity of revenues with respect to productivity $\varphi(\omega)$. It is easily verified that ξ becomes $\sigma - 1$ for $\gamma = 0$ (requiring $\theta = 0$ and $\delta \to \infty$). The elasticity ξ is smaller compared to the elasticity $\sigma - 1$ obtained in Melitz (2003). This difference stems from the fact that more productive firms pay higher wages and offer expensive workplace amenities, which weakens their advantage in terms of lower marginal production costs. Following Egger et al. (2022), the term $\kappa(\omega)$ in Eq. (1.7) can be considered as the productivity equivalent of exporting, as it also affects firm-level revenues with the elasticity of ξ.

Having determined firm-level revenues in Eq. (1.7), solutions for employment $l(\omega)$, wages $w(\omega)$, and average amenities $a(\omega)$ as a function of $r(\omega)$ can be derived. In order to obtain

$$l(\omega) = CA_L^{\beta} r(\omega)^{1-\gamma}, \quad a(\omega) = B^{\frac{1}{\delta}} C^{\frac{1}{1-\gamma}\frac{1}{\delta}} r(\omega)^{\frac{1}{\delta}}, \quad w(\omega) = BC^{\frac{\gamma}{1-\gamma}} A_L^{-\beta} r(\omega)^{\gamma}, \tag{1.8}$$

the firm's labour demand $l(\omega) = y(\omega)/\varphi(\omega)$ and the average workplace quality $a(\omega)$ from Eq. (1.4) are evaluated at $y(\omega)$ from Eq. (1.6). The firm's wage rate $w(\omega)$ then follows from the inverse labour supply function $w(\omega) = a(\omega)^{-\alpha/(1-\alpha)} l(\omega)^{\beta/(1-\beta)} A_L^{-\beta/(1-\beta)}$ evaluated at $a(\omega)$ and $l(\omega)$ from Eq. (1.8).[3] Evaluating the firm-level outcomes in Eq. (1.8) at $r(\omega)$ from Eq. (1.7) reveals that more productive firms offer higher wages and a higher average workplace quality to attract more workers. Because exporting firms are – *ceteris paribus* – larger, they pay an exporter-wage premium and offer higher average amenities relative to a non-exporting firm with similar productivity.

Eqs. (1.7) and (1.8) together imply that operating profits $\pi(\omega)$ are a constant share $\mu_\pi = [\sigma\delta - (\sigma-1)(\delta-1)(1-\beta)]/\sigma\delta \in (0,1)$ of the revenues $r(\omega)$, whereas the firm's wage bill $w(\omega)l(\omega)$ accounts for a constant share $\mu_w = \rho(1-\beta)/(1-\gamma) \in (0,1)$ of the revenues $r(\omega)$.

1.4 General equilibrium

Before determining market entry and the allocation of labour in general equilibrium, detailed microfundations for the demand and supply shifters A_G and

[3] The constant $B \equiv [\alpha/(1-\alpha)]^{(1-\beta)/(1-\gamma)} > 0$ summarizes exogeneous parameters.

A_L are provided.

1.4.1 Microfoundation of labour supply and goods demand

Following Card et al. (2018) and Egger et al. (2022), it is assumed that workers' workplace choice is governed by two factors. A worker ν cares about the wage rate $w(\omega)$ and the workplace quality $a(\nu, \omega)$ offered by employer ω. The worker-firm-specific workplace quality term $a(\nu, \omega)$ thereby captures the worker's individual preferences for non-monetary job characteristics, for example, the firm's working environment or the worker's commuting distance between residence and workplace. The indirect utility of worker ν working for firm ω therefore equals

$$v(\nu, \omega) = (1-\alpha)\ln[w(\omega)] + \alpha\hat{a}(\nu, \omega) - \bar{v}, \tag{1.9}$$

in which $\alpha \in (0,1)$ determines the relative importance of non-pecuniary job aspects that are represented by an idiosyncratic amenity draw $\hat{a}(\nu, \omega)$ from a Type I extreme value (Gumbel) distribution with dispersion parameter $\theta/(1-\theta)\alpha > 0$, firm-specific location parameter $\ln[a(\omega)]$, and cumulative density function $\exp\{-a(\omega)^{\alpha(1-\theta)/\theta}\exp[-\hat{a}(\omega)\alpha(1-\theta)/\theta]\}$[4].

The probability of worker ν to choose a job in a firm ω bringing utility $v(\nu, \omega)$ over all alternative options $\omega' \neq \omega$ is given by

$$\text{Prob}[v(\nu, \omega) \geq \max\{v(\nu, \omega')\}] = \frac{[a(\omega)^{\alpha} w(\omega)^{1-\alpha}]^{\frac{1-\theta}{\theta}}}{\int_{\omega\in\Omega}[a(\omega)^{\alpha} w(\omega)^{1-\alpha}]^{\frac{1-\theta}{\theta}} d\omega}, \tag{1.10}$$

and depends positively on the firm's average workplace quality $a(\omega)$ and on the firm's wage rate $w(\omega)$ relative to the workplace quality and wages offered by its competitors.[5] The state of the labour market, therefore, is captured by

[4] The constant utility term $\bar{v} \equiv \Gamma'(1)\theta/(1-\theta)\alpha$ summarizes various exogenous parameters with $\Gamma'(1)$ representing the Euler-Mascheroni constant.

[5] The derivation of Eq. (1.10) is delegated to Appendix 1.A.1. See also Jha and Rodriguez-Lopez (2021), who demonstrate how the results in Ben-Akiva et al. (1985) can be used to extend the discrete choice problem from Card et al. (2018) to the continuous choice set case.

the following quality-weighted wage index

$$W \equiv \left\{ \int_{\omega\in\Omega} [a(\omega)^\alpha w(\omega)^{1-\alpha}]^{\frac{1-\theta}{\theta}} d\omega \right\}^{\frac{\theta}{1-\theta}} . \tag{1.11}$$

The supply of labour $h(\omega) = A_L[a(\omega)^\alpha w(\omega)^{1-\alpha}]^{\frac{1-\theta}{\theta}}$ to firm ω is then obtained by the total labour endowment L multiplied by the firm-specific probability of employing a given worker $\left[a(\omega)^\alpha w(\omega)^{1-\alpha}/W\right]^{\frac{1-\theta}{\theta}}$, with $A_L \equiv L/W^{\frac{1-\theta}{\theta}}$ summarizing all aggregate variables.

The elasticity $(1-\theta)/\theta$ determines the responsiveness of labour supply with respect to changes in the compensation bundle $a(\omega)^\alpha w(\omega)^{1-\alpha}$. if $\theta = 0$, firms do not differ in terms of their workplace quality. Workplaces, therefore, are perceived as perfect substitutes, which is why labour supply becomes perfectly elastic. The labour market then reaches its competitive limit, with all firms paying the same wage as, for example, in Melitz (2003).

Similar to Ethier (1982) and Egger et al. (2022), the homogeneous consumption good $X = \left[\widehat{M}^{-\frac{1}{\sigma}} \int_{\omega\in\Omega} x(\omega)^{\frac{\sigma-1}{\sigma}} d\omega\right]^{\frac{\sigma}{\sigma-1}}$ is produced by combining the differentiated inputs provided by the manufacturing firms, where Ω represents the set of available inputs. As in Blanchard and Giavazzi (2003) and Egger and Kreickemeier (2009), external scale economies are ruled out by assumption[6]. By eliminating external scale economies, which is already well understood from Ethier (1982), the various fixed costs in the model, which are accounted for in units of the final consumption good, are not subject to external increasing returns to scale and therefore do not depend on country size.[7] By normalizing the price of the final consumption good to one, i.e. $P = \left[\widehat{M}^{-1} \int_{\omega\in\Omega} p(\omega)^{1-\sigma} d\omega\right]^{\frac{1}{1-\sigma}} \stackrel{!}{=} 1$, the demand shifter A_G can be solved as $X/\widehat{M}$.

[6] For more technical details, see Egger and Kreickemeier (2009).

[7] See Jha and Rodriguez-Lopez (2021) for an example, in which fixed costs are subject to external scale economies, which results in the additional parameter constraint $\sigma > 2$, that is needed to ensure that larger countries have more firms, and in a non-constant worker-to-firm ratio, that is an increasing function of country size.

1.4.2 Market entry

The indifference condition $\pi_d(\varphi_d) = f_d$ yields a productivity level $\varphi_d > 0$ at which a firm makes zero profits. Therefore, the cutoff productivity φ_d separates firms with $\varphi \geq \varphi_d$, choosing to produce from firms with $\varphi < \varphi_d$, choosing to remain inactive.[8] The respective indifference condition for foreign market entry is given by $\pi_x(\varphi_x) - \pi_d(\varphi_x) = f_x$. The share of exporting firms can therefore be derived as

$$\chi = \frac{1 - G(\varphi_x)}{1 - G(\varphi_d)} = \left(\frac{\varphi_d}{\varphi_x}\right)^g = \left[\frac{\pi_d(\varphi_d)}{\pi_d(\varphi_x)}\right]^{\frac{g}{\xi}} = \left[\frac{\pi_d(\varphi_d)}{\pi_x(\varphi_x) - \pi_d(\varphi_x)} \frac{\pi_x(\varphi_x) - \pi_d(\varphi_x)}{\pi_d(\varphi_x)}\right]^{\frac{g}{\xi}}$$
$$= \left[\frac{f_d}{f_x}(\kappa^{\xi} - 1)\right]^{\frac{g}{\xi}}. \tag{1.12}$$

Defining $\bar{r}_d$ as average domestic revenues and $\Delta\bar{r}_x \equiv \int_{\varphi_x}^{\infty} r_x(\varphi_x) - r_d(\varphi_x) dG(\varphi)/[1 - G(\varphi_d)]$ as the average foreign revenues that only accrue to exporting firms, the economy's domestic expenditure share can be solved

$$\lambda = \frac{\bar{r}_d}{\bar{r}_d + \chi\Delta\bar{r}_x} = \frac{r_d(\varphi_d)}{r_d(\varphi_d) + \chi[r_x(\varphi_x) - r_d(\varphi_x)]} = \frac{f_d}{f_d + \chi f_x}. \tag{1.13}$$

Eq. (1.13) exploits the direct proportionality between average and cut-off revenues $\bar{r}_d/r_d(\varphi_d) = \Delta\bar{r}_x/[r_x(\varphi_x) - r_d(\varphi_x)] = [g/(g - \xi)]$ that follows form the Pareto distribution for firm-level productivities. Conveniently, $1/\lambda \geq 1$ is a natural openness measure that nicely summarizes the effect of trade frictions, which is why the model is solved in terms of λ (rather than in terms of the underlying parameters τ and f_x).

Free market entry requires the expected profits of potential entrants to be zero:

$$0 \stackrel{!}{=} [1 - G(\varphi_d)]\{\bar{\pi} - f_d - \chi f_x\} - f_e, \tag{1.14}$$

with $[1 - G(\varphi_d)]$ as the *ex ante* probability of entering the market, $\bar{\pi}$ as the expected operating profits, and $f_d + \chi f_x$ as the expected fixed costs associated with market entry.

[8] Because firm performance can fully be characterised by the firm's productivity level φ and the firm's exporting status $i \in d, x$, the firm-specific index ω is dropped whenever possible for the simplification.

1.4.3 Factor allocation

Average operating profits $\bar{\pi} = \mu_\pi[\bar{r}_d + \chi\Delta\bar{r}_x]$ are defined as the sum of average domestic profits and average exporting profits. Using the market entry conditions $\mu_\pi r_d(\varphi_d) = f_d$ and $\mu_\pi[r_x(\varphi_x) - r_d(\varphi_x)] = f_x$ in combination with Eq. (1.13) allows us to solve for $\bar{\pi} = [g/(g-\xi)]f_d/\lambda$. Substituting this expression into the free entry condition in Eq. (1.14) then yields the cut-off productivity level

$$\varphi_d = \left(\frac{\xi}{g-\xi}\frac{1}{\lambda}\frac{f_d}{f_e}\right)^{\frac{1}{g}}. \tag{1.15}$$

From the inspection of the free entry condition in Eq. (1.14), it follows that an increase in firms' expected profits by a factor $1/\lambda$ has to be offset by a stronger selection into production (i.e. a lower probability of market entrance $1 - G(\varphi_d)$), which is why firms in the open economy are on average more productive than in the closed economy.

The number of firms M is solved in two steps. At first, according to the full-employment condition, the number of firms $M = L/\bar{l}$ is determined by the ratio of aggregate labour endowment L to the average labour demand per firm $\bar{l}$. Average employment $\bar{l} = \{g/[g-(1-\gamma)\xi]\}l_d(\varphi_d)/\Lambda$ thereby is proportional to the cut-off employment level of the least productive firm $l_d(\varphi_d)$ with

$$\frac{1}{\Lambda} = 1 + \left\{\left[\left(\frac{1}{\lambda}-1\right)^{\frac{\xi}{g}}\left(\frac{f_d}{f_x}\right)^{\frac{\xi-g}{g}}+1\right]^{1-\gamma} - 1\right\}\left[\left(\frac{1}{\lambda}-1\right)\frac{f_d}{f_x}\right]^{\frac{g-(1-\gamma)\xi}{g}} \geq 1 \tag{1.16}$$

as a factor of proportionality that accounts for disproportionately higher employment levels among exporting firms.[9] Note that $1/\Lambda$ is increasing in our openness measure $1/\lambda$, taking a value of $1/\Lambda = 1$ for $1/\lambda = 1$. With constant markups and markdowns the cut-off employment level $l_d(\varphi_d)$ follows from $w_d(\varphi_d)l_d(\varphi_d)/\mu_w = r_d(\varphi_d) = \pi_d(\varphi_d)/\mu_\pi$ as $l_d(\varphi_d) = (\mu_w/\mu_\pi)f_d/w_d(\varphi_d)$ with the corresponding cut-off wage following from $p_d(\varphi_d) = (1/\rho)w_d(\varphi_d)/\varphi_d$ as $w_d(\varphi_d) = \rho\varphi_d p_d(\varphi_d)$. It moreover can be shown that the aggregate price index $P = 1$ is proportional to the cut-off price level such that $p_d(\varphi_d) = [g/(g-\xi)]^{1/(\sigma-1)}(1/\lambda)^{1/(\sigma-1)}$.[10] Putting the above pieces together allows us to

[9] The derivation of Λ in Eq. (1.16) is delegeted to Appendix 1.A.2.

[10] The aggregate price index $P = 1$ is linked to the cut-off price level $p_d(\varphi_d)$ in Appendix 1.A.3.

solve for cut-off employment and cut-off wage levels

$$l_d(\varphi_d) = \frac{\mu_w}{\mu_\pi}\frac{f_d}{w_d(\varphi_d)} = \frac{\mu_w}{\mu_\pi}\frac{f_d}{\rho}\frac{1}{\varphi_d}\frac{1}{p_d(\varphi_d)} = D\lambda^{\frac{1}{g}+\frac{1}{\sigma-1}}, \tag{1.17}$$

in which φ_d from Eq. (1.15) has been substituted.[11] The number of firms follows finally as $M = L/\bar{l} = \{[g-(1-\gamma)\xi]/g\}\Lambda L/l_d(\varphi_d)$ with $l_d(\varphi_d)$ given in Eq. (1.17).

1.4.4 Aggregate supply and demand shifters

The aggregate supply and demand shifters

$$\begin{aligned} A_L &= \left(\frac{D}{C}\right)^{\frac{1}{\beta}}\left(\frac{\mu_\pi}{f_d}\right)^{\frac{1}{\beta}\frac{1}{1-\gamma}}\lambda^{\frac{1}{\beta}\left(\frac{1}{g}+\frac{1}{\sigma-1}\right)} \\ A_G &= \left[\left(\frac{f_d}{\mu_\pi}\right)^{\frac{1}{\xi}-\frac{1}{1-\gamma}}\frac{1}{D}\left(\frac{g-\xi}{g}\frac{f_e}{f_d}\right)^{\frac{1}{g}}\right]^{\sigma-1}\frac{1}{\lambda} \end{aligned} \tag{1.18}$$

can be derived in two steps: Evaluating $l_d(\varphi) = CA_L^\beta r_d(\varphi)^{1-\gamma}$ in Eq. (1.8) at the domestic market entry condition $r_d(\varphi_d) = f_d/\mu_\pi$ and $l_d(\varphi_d)$ from Eq. (1.17) allows us to solve for A_L. The solution for A_L is then used to solve for A_G from Eq. (1.7) evaluated at the domestic market entry condition $r_d(\varphi_d) = f_d/\mu_\pi$.

1.5 Gains from trade

Aggregate welfare V is given by workers' expected utility conditional on optimal workplace choice $V = \mathbb{E}[v(\nu,\omega)|v(\nu,\omega) \geq \max_{\omega'\neq\omega}\{v(\nu,\omega')\}] = \ln W$.[12] Because $W = (L/A_L)^{\theta/(1-\theta)}$ the solution of A_L from Eq. (1.18) can be used to solve aggregate welfare as

$$V = \text{Const.} + \frac{\theta}{1-\theta}\ln L + \Delta \quad \text{with} \quad \Delta \equiv \underbrace{\frac{1-\alpha}{1-\beta}\left(\frac{1}{g}+\frac{1}{\sigma-1}\right)\ln\left(\frac{1}{\lambda}\right)}_{\text{gains from trade}}, \tag{1.19}$$

[11] The constant $D \equiv \frac{\mu_w}{\mu_\pi}\frac{f_d}{\rho}\left(\frac{f_e}{f_d}\right)^{\frac{1}{g}}\left(\frac{g}{\xi}\right)^{\frac{1}{g}}\left(\frac{g-\xi}{g}\right)^{\frac{1}{g}+\frac{1}{\sigma-1}}$ summarizes exogenous parameters.

[12] The derivation of aggregate welfare is delegated to Appendix 1.A.4.

Where $\Delta \geq 0$ evaluates the welfare gains from trade. Similar to Arkolakis et al. (2012), Eq. (1.19) uses the domestic expenditure share $(1/\lambda)$ and the trade elasticity to derive predictions on welfare changes caused by moving from autarky to any open economy equilibrium. The magnitude of the trade elasticity thereby also depends on the labour market imperfection.

Using $a(\omega)$ and $w(\omega)$ from Eq. (1.8) allows to rewrite the quality-weighted wage index W from Eq. (1.11) as $W = \{g/[g-(1-\gamma)\xi]\}^{\theta/(1-\theta)} M^{\theta/(1-\theta)} [a_d(\varphi_d)/\Lambda^{\theta/(1-\theta)}]^{\alpha} [w_d(\varphi_d)/\Lambda^{\theta/(1-\theta)}]^{1-\alpha}$. With the cut-off wage $w_d(\varphi_d)$ and the number of firms M following from Eq. (1.17), the gains from trade can be decomposed into the following three components

$$\Delta = \Delta_c + \Delta_v + \Delta_a, \tag{1.20}$$

with

$$\begin{aligned}
\Delta_c &\equiv (1-\alpha)\left(\frac{1}{g} + \frac{1}{\sigma-1}\right)\ln\left(\frac{1}{\lambda}\right) \\
&\qquad\qquad + (1-\alpha)\frac{\theta}{1-\theta}\ln\left(\frac{1}{\Lambda}\right) \quad \text{(consumption gains)}, \\
\Delta_v &\equiv \frac{\theta}{1-\theta}\left(\frac{1}{g} + \frac{1}{\sigma-1}\right)\ln\left(\frac{1}{\lambda}\right) - \frac{\theta}{1-\theta}\ln\left(\frac{1}{\Lambda}\right) \quad \text{(variety gains/losses)}, \\
\Delta_a &\equiv \alpha\frac{\theta}{1-\theta}\ln\left(\frac{1}{\Lambda}\right) \quad \text{(workplace quality gains)}
\end{aligned} \tag{1.21}$$

To quantify the importance of these three welfare channels, the relative contribution of each channel can be computed as $\hat{\Delta}_s \equiv \Delta_s/\Delta \;\; \forall \;\; s \in \{c, v, a\}$. The effects that trade liberalization has on each welfare channel can then be summarized in Proposition 1.

Proposition 1 *An increase in a country's trade openness, measured by an increase in* $1/\lambda$
a) leads to aggregate welfare gains through increased consumption ($\hat{\Delta}_c$) *and workplace quality* ($\hat{\Delta}_a$) *upgrade.*
b) leads to aggregate welfare losses due to the reduced workplace variety ($\hat{\Delta}_v$) *available on the labour market.*

Proof. *Formal derivations in Appendix 1.A.5.*

Figure 1 illustrates the relative contributions of $\hat{\Delta}_c$, $\hat{\Delta}_v$, and $\hat{\Delta}_a$ through which the gains from trade materialize. Households benefit from trade liberalization in terms of a higher average real income and, hence, more consumption, which increases aggregate welfare by $\hat{\Delta}_c \geq 0$.

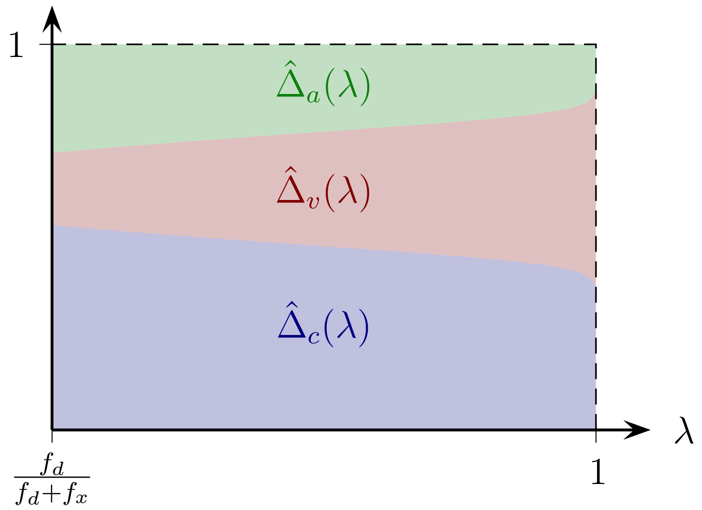

Figure 1.1: Decomposing normalised gains from trade

In addition to these familiar real-income gains, there are two non-pecuniary welfare effects that materialize through the labour market: Workers are less likely to find their ideal employer when having a limited choice of potential workplaces, and as a consequence, aggregate welfare decreases ambiguously by $\hat{\Delta}_v < 0$, relative to autarky. Because workers value not only a broad workplace choice but also the quality of their workplace amenities, there are workplace quality gains of $\hat{\Delta}_a > 0$, which follow from the endogenous workplace quality upgrading of exporting firms.

1.6 Quantitative results

This section provides the quantitative relevance of the obtained results. The primary data source of the quantitative exercise is the World Input-Output Database (WIOD) constructed by Timmer et al. (2015). The data set covers 28 EU and 15 other major countries, and the WIOD 2016 is used for the analysis. All the sectors are aggregated at the country level, and the domestic expenditure share is calculated as follows: $\lambda_{jj} = 1 - \sum_{i \neq j} X_{ij} / \sum_{i=1}^{n} X_{ij}$. Where λ_{jj} is the domestic expenditure share for a given country j. $\sum_{i \neq j} X_{ij}$ is a total imports and $\sum_{i=1} X_{ij}$ is the total expenditure by country j.

As in Melitz and Redding (2015), the elasticity of substitution between varieties σ and the shape parameter for the Pareto productivity distribution g are equal to 4 and 4.25, respectively. The θ parameter equals 0.4, which is borrowed from the recent literature on estimating the firm-specific labour supply elasticity (see Sokolova and Sorensen, 2018, for an overview). The last remaining parameter in the model is α, which captures the relative importance of workplace quality in the workers' preferences. Due to the data unavailability, the welfare gains from trade are calculated for each possible value of α. While the different alpha values change the magnitude of the quantitive results, they still do not affect the main predictions of the theoretical model developed in this chapter. In particular, the welfare gains from trade under monopsonistic competition with endogenous workplace quality upgrading are always higher than the gains from trade under frictionless labour markets. In the baseline results, α is equal to 0.2. Appendix 1.A.6 reports the welfare gains from trade for alternative values of α.

The main results are reported in Table 1.1. The second column reports the welfare gains obtained under the assumption of a perfectly competitive labour market. The third column reports the welfare gains obtained under monopolistic competition with endogenous workplace quality upgrades. In the second column, the welfare gains from trade tend to be below 4% for the big economies. On the contrary, smaller countries, such as Ireland (26.9%) or Estonia (17.65%), benefit more from trade openness (see also Costinot and Rodríguez-Clare (2014)).

This quantitative exercise also shows that, for each country reported in Table 1.1, the gains from trade are higher under monopsonistic competition with endogenous workplace quality upgrading. Aggregate welfare gains are higher under monopsonistic competition as trade liberalization reduces monopsony distortions by relocating domestic resources from least productive to more productive firms (see also Egger et al., 2022). In addition to this, the gains from trade not only materialise in terms of a higher purchasing power but also in terms of a higher average workplace quality.

Table 1.1: Welfare gains from trade

Country	Perfect comp. labor market	Monopsonistic comp. with amenity upgrade
AUS	4.88%	7.16%
AUT	12.26%	17.99%
BEL	17.31%	25.39%
BGR	13.99%	20.51%
BRA	3.46%	5.08%
CAN	8.03%	11.78%
CHE	9.85%	14.44%
CHN	2.65%	3.89%
CYP	13.63%	19.99%
CZE	15.55%	22.81%
DEU	9.36%	13.73%
DNK	12.19%	17.88%
ESP	7.03%	10.32%
EST	17.65%	25.88%
FIN	9.22%	13.52%
FRA	7.29%	10.69%
GBR	6.83%	10.02%
GRC	9.13%	13.39%
HRV	11.73%	17.2%
HUN	21.22%	31.12%
IDN	5.51%	8.09%
IND	4.27%	6.26%
IRL	26.9%	39.46%
ITA	6.05%	8.87%
JPN	4.67%	6.85%
KOR	8.22%	12.06%
LTU	19.77%	29.0%
LUX	32.25%	47.3%
LVA	11.8%	17.31%
MEX	8.12%	11.91%
MLT	27.4%	40.19%
NLD	15.01%	22.01%
NOR	7.73%	11.34%
POL	10.49%	15.38%
PRT	9.6%	14.07%
ROU	9.4%	13.79%
ROW	9.16%	13.43%
RUS	5.37%	7.87%
SVK	17.93%	26.29%
SVN	16.21%	23.77%
SWE	10.07%	14.77%
TUR	7.39%	10.83%
USA	3.47%	5.08%
Average	11.43%	16.76%

Note: All data is from WIOD. Trade elasticities are from Melitz and Redding (2015). Labour supply elasticity is from Sokolova and Sorensen (2018). The results in the second column are obtained by setting $\beta = 0$ and $\alpha = 0$ in Eq. (1.19).

1.7 Conclusion

This chapter introduces endogenous workplace quality choice into an international trade model with a monopsonistically competitive labour market, in which firms compete for potential employees by offering them a combination of monetary and non-monetary benefits. To attract the workers required to produce for the foreign market in addition to the domestic market, exporting firms have to offer more attractive compensation to their employees than comparable non-exporting firms, which is why they are not only paying higher wages but also offering better workplace amenities. The gains from trade, therefore, not only materialise in terms of a higher purchasing power but also in terms of a higher average workplace quality. Welfare metrics, which exclusively focus on real income gains, may therefore underestimate the gains from globalisation.

1.A Appendix

1.A.1 Microfundation of labour supply

As in Egger et al. (2022), for a given draw $\hat{a}(\nu,\omega)$ the probability of worker ν to choose firm ω is given by $\text{Prob}[v(\nu,\omega) \geq \max_{\omega'\neq\omega}\{v(\nu,\omega')\}|\hat{a}(\nu,\omega)] = \text{Prob}[\,\cdot\,|\hat{a}(\nu,\omega)]$ with

$$\begin{aligned}
\text{Prob}[\,\cdot\,|\hat{a}(\nu,\omega)] &= \prod_{\omega'\neq\omega} \text{Prob}\Big[v(\nu,\omega) \geq v(\nu,\omega')|\hat{a}(\nu,\omega)\Big] \\
&= \prod_{\omega'\neq\omega} \text{Prob}\Big(\hat{a}(\nu,\omega') \leq \hat{a}(\nu,\omega) + \frac{1-\alpha}{\alpha}\Big\{\ln[w(\omega)] - \ln[w(\omega')]\Big\}\Big) \\
&= \prod_{\omega'\neq\omega} \exp\Big(-a(\omega')^{\frac{1-\theta}{\theta}\alpha} \exp\Big\{-\frac{1-\theta}{\theta}\Big[\alpha\hat{a}(\nu,\omega) \\
&\quad + (1-\alpha)\{\ln[w(\omega)] - \ln[w(\omega')]\}\Big]\Big\}\Big).
\end{aligned}$$

The *ex ante* probability $\text{Prob}[v(\nu,\omega) \geq \max_{\omega'\neq\omega}\{v(\nu,\omega')\}] = \text{Prob}[\,\cdot\,]$ of worker ν choosing firm ω can then be computed as

$$\begin{aligned}
\text{Prob}[\,\cdot\,] &= \int_{-\infty}^{\infty} \text{Prob}[v(\nu,\omega) \geq \max_{\omega'\neq\omega}\{v(\nu,\omega')\}|\hat{a}(\nu,\omega)] \\
&\times \frac{1-\theta}{\theta}\alpha a(\omega)^{\frac{1-\theta}{\theta}\alpha} \exp\Big[-\frac{1-\theta}{\theta}\alpha\hat{a}(\nu,\omega)\Big] \\
&\times \exp\Big\{-a(\omega)^{\frac{1-\theta}{\theta}\alpha} \exp\Big[-\frac{1-\theta}{\theta}\alpha\hat{a}(\nu,\omega)\Big]\Big\} d\hat{a}(\nu,\omega) \\
&= \int_{-\infty}^{\infty} \prod_{\omega'\neq\omega} \exp\Big(-a(\omega')^{\frac{1-\theta}{\theta}\alpha} \\
&\times \exp\Big\{-\frac{1-\theta}{\theta}\Big[\alpha\hat{a}(\nu,\omega) + (1-\alpha)\{\ln[w(\omega)] - \ln[w(\omega')]\}\Big]\Big\}\Big) \\
&\times \frac{1-\theta}{\theta}\alpha a(\omega)^{\frac{1-\theta}{\theta}\alpha} \exp\Big[-\frac{1-\theta}{\theta}\alpha\hat{a}(\nu,\omega)\Big] \\
&\times \exp\Big\{-a(\omega)^{\frac{1-\theta}{\theta}\alpha} \exp\Big[-\frac{1-\theta}{\theta}\alpha\hat{a}(\nu,\omega)\Big]\Big\} d\hat{a}(\nu,\omega) \\
&= \int_{-\infty}^{\infty} \exp\left[- a(\omega)^{\frac{1-\theta}{\theta}\alpha} \exp\Big[-\frac{1-\theta}{\theta}\alpha\hat{a}(\nu,\omega)\Big]\right. \qquad (1.22) \\
&\times \left(1 + \sum_{\omega'\neq\omega} \exp\left\{ - \frac{1-\theta}{\theta}[(1-\alpha)\{\ln[w(\omega)] - \ln[w(\omega')]\}\right.\right.
\end{aligned}$$

$$
\begin{aligned}
&+ \alpha\{\ln[a(\omega)] - \ln[a(\omega')]\}]\Big\}\Big)\Big]\\
&\times \frac{1-\theta}{\theta}\alpha a(\omega)^{\frac{1-\theta}{\theta}\alpha}\exp\Big[-\frac{1-\theta}{\theta}\alpha\hat{a}(\nu,\omega)\Big]d\hat{a}(\nu,\omega)\\
&= \int_{-\infty}^{\infty}\exp\Bigg\{-a(\omega)^{\frac{1-\theta}{\theta}\alpha}\exp\left[-\frac{1-\theta}{\theta}\alpha\hat{a}(\nu,\omega)\right]\\
&\times\left(\sum_{\omega'}\left\{\left[\frac{a(\omega')}{a(\omega)}\right]^{\alpha}\left[\frac{w(\omega')}{w(\omega)}\right]^{1-\alpha}\right\}^{\frac{1-\theta}{\theta}}\right)\Bigg\}\\
&\times\frac{1-\theta}{\theta}\alpha a(\omega)^{\frac{1-\theta}{\theta}\alpha}\exp\left[-\frac{1-\theta}{\theta}\alpha\hat{a}(\nu,\omega)\right]d\hat{a}(\nu,\omega).
\end{aligned}
$$

Introducing the definition $b(\nu,\omega) = a(\omega)^{\frac{1-\theta}{\theta}\alpha}\exp\{-[(1-\theta)/\theta]\alpha\hat{a}(\nu,\omega)\}$ with the corresponding derivative $db(\nu,\omega) = -[(1-\theta)/\theta]\alpha a(\omega)^{\frac{1-\theta}{\theta}\alpha}\exp\{-[(1-\theta)/\theta]$ $\alpha\hat{a}(\nu,\omega)\}d\hat{a}(\nu,\omega)$ allows us to change the variable of integration

$$
\begin{aligned}
&\text{Prob}[v(\nu,\omega) \geq \max_{\omega'\neq\omega}\{v(\nu,\omega')\}] =\\
&= \int_{-\infty}^{\infty}\exp\left(-b(\nu,\omega)\sum_{\omega'}\left\{\left[\frac{a(\omega')}{a(\omega)}\right]^{\alpha}\left[\frac{w(\omega')}{w(\omega)}\right]^{1-\alpha}\right\}^{\frac{1-\theta}{\theta}}\right)db(\nu,\omega)\\
&= \left|\frac{\exp\left(-b(\nu,\omega)\sum_{\omega'}\left\{\left[\frac{a(\omega')}{a(\omega)}\right]^{\alpha}\left[\frac{w(\omega')}{w(\omega)}\right]^{1-\alpha}\right\}^{\frac{1-\theta}{\theta}}\right)}{\sum_{\omega'}\left\{\left[\frac{a(\omega')}{a(\omega)}\right]^{\alpha}\left[\frac{w(\omega')}{w(\omega)}\right]^{1-\alpha}\right\}^{\frac{1-\theta}{\theta}}}\right|_{0}^{\infty} \qquad (1.23)\\
&= \left[\frac{a(\omega)^{\alpha}w(\omega)^{1-\alpha}}{W}\right]^{\frac{1-\theta}{\theta}},
\end{aligned}
$$

with $W \equiv \{\sum_{\omega'}[a(\omega')^{\alpha}w(\omega')^{1-\alpha}]^{\frac{1-\theta}{\theta}}\}^{\frac{\theta}{1-\theta}}$, which in the notation of measure and integration theory can be expressed as the definite integral

$$
W = \left\{\int_{\omega\in\Omega}\left[a(\omega)^{\alpha}w(\omega)^{1-\alpha}\right]^{\frac{1-\theta}{\theta}}d\omega\right\}^{\frac{\theta}{1-\theta}}, \qquad (1.24)
$$

with Ω denoting the set of firms.

1.A.2 Aggregate labour demand

Following Egger et al. (2022), the full-employment condition aggregate labour endowment L has to equal aggregate labour demand

$$L = M\Big[\int_{\varphi_d}^{\infty} l_d(\varphi)\frac{dG(\varphi)}{1-G(\varphi_d)} + \int_{\varphi_d}^{\infty} l_x(\varphi) - l_d(\varphi)\frac{dG(\varphi)}{1-G(\varphi_d)}\Big] \tag{1.25}$$
$$= Ml_d(\varphi_d)\Big[\int_{\varphi_d}^{\infty} \frac{l_d(\varphi)}{l_d(\varphi_d)}\frac{dG(\varphi)}{1-G(\varphi_d)} + \int_{\varphi_x}^{\infty} \frac{l_x(\varphi)-l_d(\varphi)}{l_d(\varphi)}\frac{l_d(\varphi)}{l_d(\varphi_x)}\frac{l_d(\varphi_x)}{l_d(\varphi_d)}$$
$$\times \frac{1-G(\varphi_x)}{1-G(\varphi_d)}\frac{dG(\varphi)}{1-G(\varphi_x)}\Big].$$

According to Eq. (1.8), $l_d(\varphi)/l_d(\varphi_i) = (\varphi/\varphi_i)^{(1-\gamma)\xi}\ \forall\ i \in \{d, x\}$ and $[l_x(\varphi) - l_d(\varphi)]/l_d(\varphi) = \kappa^{(1-\gamma)\xi} - 1$. Together the Eqs. (1.12) and (1.8) moreover imply that $l_d(\varphi_x)/l_d(\varphi_d) = \chi^{-(1-\gamma)\xi/g}$. Using $[1 - G(\varphi_x)]/[1 - G(\varphi_d]$ from Eq. (1.12) therefore allows to derive $L = \{g/[g-(1-\gamma)\xi]\}\frac{Ml_d(\varphi_d)}{\Lambda}$ with $\frac{1}{\Lambda} \equiv 1+[\kappa^{(1-\gamma)\xi} - 1]\chi^{[g-(1-\gamma)\xi]/g}$. Using the Eqs. (1.12) and (1.13) to replace κ and χ yields $\frac{1}{\Lambda}$ as defined in Eq. (1.16).

1.A.3 Aggregate price index

Following Egger et al. (2022), the aggregate price index is defined as

$$P^{1-\sigma} = \int_{\varphi_d}^{\infty} p_d(\varphi)^{1-\sigma}\frac{dG(\varphi_d)}{1-G(\varphi_d)} + \int_{\varphi_d}^{\infty} p_x(\varphi)^{1-\sigma} + [\tau p_x(\varphi)]^{1-\sigma}\frac{dG(\varphi_d)}{1-G(\varphi_d)}$$
$$= p_d(\varphi_d)^{1-\sigma}\Bigg\{\int_{\varphi_d}^{\infty}\Big[\frac{p_d(\varphi)}{p_d(\varphi_d)}\Big]^{1-\sigma}\frac{dG(\varphi_d)}{1-G(\varphi_d)} \tag{1.26}$$
$$+ \int_{\varphi_x}^{\infty} \frac{p_x(\varphi)^{1-\sigma} + [\tau p_x(\varphi)]^{1-\sigma} - p_d(\varphi)^{1-\sigma}}{p_d(\varphi)^{1-\sigma}}\Big[\frac{p_d(\varphi)}{p_d(\varphi_x)}\frac{p_d(\varphi_x)}{p_d(\varphi_d)}\Big]^{1-\sigma} \tag{1.27}$$
$$\times \frac{1-G(\varphi_x)}{1-G(\varphi_d)}\frac{dG(\varphi)}{1-G(\varphi_x)}\Bigg\}.$$

Eqs. (1.7) and (1.8) together imply that $[p_d(\varphi)/p_d(\varphi_d)]^{1-\sigma} = \{[w_d(\varphi)/\varphi]/[w_d(\varphi_d)/\varphi_d]\}^{1-\sigma} = (\varphi/\varphi_d)^{\xi}$ and that $[p_d(\varphi_x)/p_d(\varphi_d)]^{1-\sigma} = \{[w_d(\varphi_x)/\varphi_x]/[w_d(\varphi_d)/\varphi_d]\}^{1-\sigma} = (\varphi_x/\varphi_d)^{\xi} = r_d(\varphi_x)/r_d(\varphi_d)$. In combination with the definition of κ from Eq. (1.2), the Eqs. (1.7) and (1.8) moreover imply that $(1 + \tau^{1-\sigma})p_x(\varphi)/p_d(\varphi) = \kappa^{\xi} = r_x(\varphi_x)/r_d(\varphi_x)$. In the light of the market entry conditions $r_d(\varphi_d) = f_d/\mu_\pi$ and $r_x(\varphi_x) - r_d(\varphi_x) = f_x/\mu_\pi$ the aggregate price index can then be solved as $P = [g/(g-\xi)]^{1/(\sigma-1)}(1+\chi f_x/f_d)^{1/(1-\sigma)}p_d(\varphi_d) = [g/(g-\xi)]^{1/(1-\sigma)}(1/\lambda)^{1/(1-\sigma)}p_d(\varphi_d)$.

1.A.4 Aggregate welfare

As already shown in Egger et al. (2022), expected utility equals

$$\begin{aligned}\mathbb{E}[v(\nu,\omega)|v(\nu,\omega) \geq \max_{\omega'\neq\omega}\{v(\nu,\omega')\}] = (1-\alpha)\ln[w(\omega)] + \alpha\mathbb{E}[\hat{a}(\nu,\omega)|v(\nu,\omega) \\ \geq \max_{\omega'\neq\omega}\{v(\nu,\omega')\}] - \bar{v}. \qquad (1.28)\end{aligned}$$

The *ex-ante* expected amenity level of workers choosing firm ω can be computed as

$$\begin{aligned}\mathbb{E}[\hat{a}(\omega)|v(\nu,\omega) \geq \max_{\omega'\neq\omega}\{v(\nu,\omega')\}] = \frac{1}{\text{Prob}[v(\nu,\omega) \geq \max_{\omega'\neq\omega}\{v(\nu,\omega')\}]} \\ \times \int_{-\infty}^{\infty} a(\omega)^{\frac{1-\theta}{\theta}\alpha} \exp\Big[-\frac{1-\theta}{\theta}\alpha\hat{a}(\nu,\omega)\Big]\frac{1-\theta}{\theta}\alpha\hat{a}(\nu,\omega) \\ \times \exp\Bigg\{-a(\omega)^{\frac{1-\theta}{\theta}\alpha}\exp\Big[-\frac{1-\theta}{\theta}\alpha\hat{a}(\nu,\omega)\Big] \\ \Big[\frac{W}{a(\omega)^{\alpha}w(\omega)^{1-\alpha}}\Big]^{\frac{1-\theta}{\theta}}\Bigg\} d\hat{a}(\nu,\omega). \qquad (1.29)\end{aligned}$$

Defining $\hat{b}(\nu,\omega) \equiv \{W/[a(\omega)^{\alpha}w(\omega)^{1-\alpha}\}^{\frac{1-\theta}{\theta}}b(\nu,\omega)$, such that $d\hat{b}(\nu,\omega) = \{W/[a(\omega)^{\alpha}(\omega)^{1-\alpha}\}^{\frac{1-\theta}{\theta}}db(\nu,\omega)$, and $\hat{a}(\nu,\omega) = -\frac{\theta}{1-\theta}\frac{1}{\alpha}\ln[\hat{b}(\nu\omega)]+\frac{1}{\alpha}\ln(W)-\frac{1-\alpha}{\alpha}\ln[w(\omega)]$, can be computed

$$\begin{aligned}\mathbb{E}[\hat{a}(\omega)|v(\nu,\omega) \geq \max_{\omega'\neq\omega}\{v(\nu,\omega')\}] = -\frac{\theta}{1-\theta}\frac{1}{\alpha}\int_{0}^{\infty}\ln[\hat{b}(\nu,\omega)]\exp[-\hat{b}(\nu,\omega)]d\hat{b}(\nu,\omega) \\ + \frac{1}{\alpha}\ln(W) - \frac{1-\alpha}{\alpha}\ln[w(\omega)], \qquad (1.30)\end{aligned}$$

which implies that $\mathbb{E}[v(\nu,\omega)|v(\nu,\omega) \geq \max_{\omega'\neq\omega}\{v(\nu,\omega')\}] = \ln(W)$.

1.A.5 Derivation and discussion of proposition 1

Relative contribution of each partial effect can be computed as $\hat{\Delta}_s \equiv \Delta_s/\Delta \;\forall\; s \in \{c, v, a\}$

$$\begin{aligned}\hat{\Delta}_c &= (1-\beta)\left[1+\frac{\theta}{1-\theta}\left(\frac{1}{g}+\frac{1}{\sigma-1}\right)^{-1}\frac{\ln(\Lambda)}{\ln(\lambda)}\right],\\ \hat{\Delta}_v &= \beta\left[1-\left(\frac{1}{g}+\frac{1}{\sigma-1}\right)^{-1}\frac{\ln(\Lambda)}{\ln(\lambda)}\right],\\ \hat{\Delta}_a &= \beta\alpha\left(\frac{1}{g}+\frac{1}{\sigma-1}\right)^{-1}\frac{\ln(\Lambda)}{\ln(\lambda)}.\end{aligned} \tag{1.31}$$

The derivative of each partial effect in Eq. 1.A.5 with respect to λ can be computed as

$$\frac{d\hat{\Delta}_c}{d\lambda} = (1-\beta)\frac{\theta}{1-\theta}\left(\frac{1}{g}+\frac{1}{\sigma-1}\right)^{-1}\left[\ln\left(\frac{1}{\lambda}\right)\right]^{-1}\frac{1}{\lambda}\left[\frac{\ln(\Lambda)}{\ln(\lambda)}-\frac{d\Lambda}{d\lambda}\frac{\lambda}{\Lambda}\right], \tag{1.32}$$

$$\frac{d\hat{\Delta}_v}{d\lambda} = -\beta\left(\frac{1}{g}+\frac{1}{\sigma-1}\right)^{-1}\left[\ln\left(\frac{1}{\lambda}\right)\right]^{-1}\frac{1}{\lambda}\left[\frac{\ln(\Lambda)}{\ln(\lambda)}-\frac{d\Lambda}{d\lambda}\frac{\lambda}{\Lambda}\right], \tag{1.33}$$

$$\frac{d\hat{\Delta}_a}{d\lambda} = \beta\alpha\left(\frac{1}{g}+\frac{1}{\sigma-1}\right)^{-1}\left[\ln\left(\frac{1}{\lambda}\right)\right]^{-1}\frac{1}{\lambda}\left[\frac{\ln(\Lambda)}{\ln(\lambda)}-\frac{d\Lambda}{d\lambda}\frac{\lambda}{\Lambda}\right], \tag{1.34}$$

with

$$\frac{d\Lambda}{d\lambda}\frac{\lambda}{\Lambda} = \left\{1-(1-\gamma)\frac{\xi}{g}\left[1+\left(\frac{1}{\lambda}-1\right)^{\frac{\xi}{g}}\left(\frac{f_d}{f_x}\right)^{\frac{\xi-g}{g}}\right]^{-1}\right\}\frac{1-\Lambda}{1-\lambda} < 1, \tag{1.35}$$

due to $\lambda \leq \Lambda$. In the following, the proof that $\frac{\ln(\Lambda)}{\ln(\lambda)} - \frac{d\Lambda}{d\lambda}\frac{\lambda}{\Lambda} \leq 0$ is obtained by contradiction. Let assume that $\frac{\ln(\Lambda)}{\ln(\lambda)} - \frac{d\Lambda}{d\lambda}\frac{\lambda}{\Lambda} > 0$, which is equivalent to

$$\Psi(\lambda) \equiv \frac{\ln(\Lambda)}{1-\Lambda}\frac{1-\lambda}{\ln(\lambda)} > \left\{1-(1-\gamma)\frac{\xi}{g}\left[1+\left(\frac{1}{\lambda}-1\right)^{\frac{\xi}{g}}\left(\frac{f_d}{f_x}\right)^{\frac{\xi-g}{g}}\right]^{-1}\right\}. \tag{1.36}$$

For Eq. (1.36) to hold at all possible parameter values (e.g. $g \to \infty$) it is required that $\Psi(\lambda) > 1$. Note that $\lim_{\lambda\to 1}\Psi(\lambda) = 1$. A contradiction would therefore arise if $d\Psi(\lambda)/d\lambda > 0$. Note that

$$\begin{aligned}\frac{d\Psi(\lambda)}{d\lambda} = \frac{\ln(\Lambda)}{\ln(\lambda)}\frac{1}{1-\Lambda}\Bigg\{&\frac{1-\lambda}{\lambda}\frac{\Lambda}{1-\Lambda}\left[\frac{\ln(\Lambda)}{\ln(\lambda)} - \frac{1-\Lambda}{\Lambda}\frac{\lambda}{1-\lambda}\right] \\ &+ \frac{1-\lambda}{\lambda}\left[\frac{1}{\ln(1/\Lambda)} - \frac{\Lambda}{1-\Lambda}\right]\left[\frac{\ln(\Lambda)}{\ln(\lambda)} - \frac{d\Lambda}{d\lambda}\frac{\lambda}{\Lambda}\right]\Bigg\},\end{aligned} \tag{1.37}$$

has a positive sign if $\frac{\ln(\Lambda)}{\ln(\lambda)} > \frac{d\Lambda}{d\lambda}\frac{\lambda}{\Lambda}$ given that $\frac{1-\Lambda}{\Lambda} \geq \ln(1/\Lambda)\ \forall\ \Lambda \in [0,1]$ and $\ln(\Lambda)\Lambda/(1-\Lambda) < \ln(\lambda)\lambda/(1-\lambda)$ if $\Lambda > \lambda$. Therefore it can be concluded that $\frac{\ln(\Lambda)}{\ln(\lambda)} - \frac{d\Lambda}{d\lambda}\frac{\lambda}{\Lambda} > 0$ implies $d\Psi(\lambda)/d\lambda > 0$ and $\Psi(\lambda) < 1$, which contradicts $\frac{\ln(\Lambda)}{\ln(\lambda)} - \frac{d\Lambda}{d\lambda}\frac{\lambda}{\Lambda} > 0$. This completes the proof.

1.A.6 Welfare gains from trade

Table 1.2: Welfare gains from trade under alternative parameter values

Country	Perfect comp. labor market	Monopsonistic comp. with amenity upgrade
AUS	4.88%	7.64%
AUT	12.26%	19.21%
BEL	17.31%	27.12%
BGR	13.99%	21.91%
BRA	3.46%	5.42%
CAN	8.03%	12.58%
CHE	9.85%	15.42%
CHN	2.65%	4.16%
CYP	13.63%	21.35%
CZE	15.55%	24.36%
DEU	9.36%	14.67%
DNK	12.19%	19.09%
ESP	7.03%	11.02%
EST	17.65%	27.65%
FIN	9.22%	14.44%
FRA	7.29%	11.42%
GBR	6.83%	10.7%
GRC	9.13%	14.3%
HRV	11.73%	18.38%
HUN	21.22%	33.24%
IDN	5.51%	8.64%
IND	4.27%	6.68%
IRL	26.9%	42.15%
ITA	6.05%	9.48%
JPN	4.67%	7.32%
KOR	8.22%	12.88%
LTU	19.77%	30.98%
LUX	32.25%	50.52%
LVA	11.8%	18.49%
MEX	8.12%	12.72%
MLT	27.4%	42.93%
NLD	15.01%	23.51%
NOR	7.73%	12.11%
POL	10.49%	16.43%
PRT	9.6%	15.03%
ROU	9.4%	14.73%
ROW	9.16%	14.35%
RUS	5.37%	8.41%
SVK	17.93%	28.09%
SVN	16.21%	25.4%
SWE	10.07%	15.78%
TUR	7.39%	11.57%
TWN	12.89%	20.2%
USA	3.47%	5.43%

Note: All data is from WIOD. Trade elasticiteis are from Melitz and Redding (2015), $\sigma = 4$ and $g = 4.25$. Labour supply elasticity is from Sokolova and Sorensen (2018), $\theta = 0.4$. $\alpha = 0.1$ The results in the second column are obtained by setting $\beta = 0$ and $\alpha = 0$ in Eq. (1.19).

Table 1.3: Welfare gains from trade under alternative parameter values

Country	Perfect comp. labor market	Monopsonistic comp. with amenity upgrade
AUS	4.88%	5.2%
AUT	12.26%	13.08%
BEL	17.31%	18.47%
BGR	13.99%	14.92%
BRA	3.46%	3.69%
CAN	8.03%	8.56%
CHE	9.85%	10.5%
CHN	2.65%	2.83%
CYP	13.63%	14.54%
CZE	15.55%	16.59%
DEU	9.36%	9.98%
DNK	12.19%	13.0%
ESP	7.03%	7.5%
EST	17.65%	18.82%
FIN	9.22%	9.83%
FRA	7.29%	7.77%
GBR	6.83%	7.29%
GRC	9.13%	9.74%
HRV	11.73%	12.51%
HUN	21.22%	22.63%
IDN	5.51%	5.88%
IND	4.27%	4.55%
IRL	26.9%	28.7%
ITA	6.05%	6.45%
JPN	4.67%	4.98%
KOR	8.22%	8.77%
LTU	19.77%	21.09%
LUX	32.25%	34.4%
LVA	11.8%	12.59%
MEX	8.12%	8.66%
MLT	27.4%	29.23%
NLD	15.01%	16.01%
NOR	7.73%	8.25%
POL	10.49%	11.19%
PRT	9.6%	10.24%
ROU	9.4%	10.03%
ROW	9.16%	9.77%
RUS	5.37%	5.72%
SVK	17.93%	19.12%
SVN	16.21%	17.29%
SWE	10.07%	10.74%
TUR	7.39%	7.88%
TWN	12.89%	13.75%
USA	3.47%	3.7%

Note: All data is from WIOD. Trade elasticiteis are from Melitz and Redding (2015), $\sigma = 4$ and $g = 4.25$. Labour supply elasticity is from Sokolova and Sorensen (2018), $\theta = 0.4$. $\alpha = 0.6$ The results in the second column are obtained by setting $\beta = 0$ and $\alpha = 0$ in Eq. (1.19).

CHAPTER 2

Trade liberalization and regional production fragmentation

2.1 Publication details

Paper II (Chapter 2):

Trade liberalization and regional production fragmentation

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Abstract:

This chapter studies to what extent trade liberalization affects regional production fragmentation. Using the input-output tables from the European Union (EU), we derive the regional value-added to gross exports (RVAX) ratio, which measures the intensity of production fragmentation across the EU regions. Exploiting the tariff variation followed by the 2004 EU enlargement, we find that a one percentage point decrease in tariff rates is associated with a 3.2% reduction in the RVAX ratio. Our findings imply that regions facing the larger tariff cuts due to the 2004 EU enlargement increased their engagement in cross-border production chains compared to the other regions. Moreover, we trace out the adjustment dynamics of the RVAX ratio and show that the effect of the tariff reduction, followed by the 2004 EU enlargement, grew over time.

Publication details:

Working paper.

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2.2 Introduction

We use regional input-output data from the European Union (EU) to study the effect of trade liberalization on regional production fragmentation in the EU. Following Johnson and Noguera (2012), we calculate the regional value-added to gross exports (RVAX) ratio to measure the intensity of production sharing across the EU NUTS2 regions. We exploit a unique policy variation associated with the 2004 EU enlargement – abolishing the trade-related tariffs between the EU states and ten new countries joining the EU. Using a gravity-style specification, we quantify the impact of regional tariff reduction on the RVAX ratio. Our findings reveal that a one percentage point decrease in tariff rate between EU member states leads to a 3.2% increase in regional production fragmentation as measured by RVAX. Our results could be interpreted as follows: EU regions facing higher tariff cuts after the EU enlargement got more engaged in cross-border production sharing and increased their trade with their bilateral partners through the regional value chains.

In recent decades, the world has witnessed a significant increase in countries' engagement in cross-border production chains. As documented by Johnson and Noguera (2012), trade in intermediates accounts for two-thirds of the world's international trade. The fragmented production process implies that the different stages of production are performed in different locations, and consequently, intermediate inputs cross borders multiple times. As a result, conventional gross trade statistics prove to be less dependable in accurately assessing a nation's participation in global value chains (GVCs). Inaccuracy comes from the fact that gross exports or imports fail to reflect the source of the value-added embodied within a given product and may encompass substantial double-counting. Recent studies in international trade usually use the value-added content of trade to measure GVCs activity worldwide. For example, Johnson and Noguera (2012) proposes a method to measure the intensity of production-sharing by comparing countries' gross and value-added exports to each other. The intuition of the method is straightforward: If a country's value added to gross exports ratio falls due to the exogenous trade shock, the decline can only be explained by the increased intensity of intermediate goods crossing borders multiple times.

Even though international trade literature has progressed in measuring and understanding the organization of global supply chains (see Antràs and Chor, 2022, for an overview), most studies in the field treat countries as a ”point in space” and neglect the regional dimensions within the countries. This chapter fills this gap by analyzing regions’ participation in cross-border production sharing. Using the regional input-output database (EUREGIO) constructed by Thissen et al. (2018), we compute the RVAX ratio for the EU NUTS2 regions from 2000 to 2010. As in Johnson and Noguera (2012), we use the RVAX ratio as an inverse measure of the regional production fragmentation. We document that the RVAX ratio has decreased over time within the EU, and there is a substantial RVAX heterogeneity across regions, which is invisible in the case of a country-level analysis.

Being equipped with a well-grounded empirical measure of EU regions’ cross-border input-output networks, we study the effect of the EU 2004 enlargement on regional production fragmentation. On 1st of May 2004, ten countries (henceforth - Non-Member States (NMS))[2] joined the EU (henceforth - EU15). As a result, all bilateral tariffs between EU15 and NMS were reduced to zero. We exploit this unique trade policy variation to identify the impact of goods market integration on regional production linkages within the EU. Using the EUREGIO database, we quantify the effects of trade policy changes at a granular level, as the data covers 249 EU NUTS2 regions and 16 tradable sectors from 2000 to 2010. Following the latest literature studying the spatial effects of trade policies (see Caliendo and Parro, 2022, for an overview), we assume that trade shocks are heterogeneous across sectors and economic activity is unevenly distributed across EU regions. We, thereby, use a shift-share method, where the bilateral tariffs are used as ”shifters”, and regional employment weights serve as a ”share”. The shift-share method allows us to identify the differential effects of trade policy changes associated with the 2004 EU enlargement on regional-level outcomes.

To quantify the effect of the 2004 EU enlargement on regional production fragmentation, we use a theory-consistent gravity style specification, which is already well-established in international trade literature (see Head and Mayer, 2014, for an overview). First, we estimate the effect of tariff changes on gross

[2] Those countries are Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, and Slovenia

and value-added bilateral exports within the EU. Our results show that a one percentage point decrease in the tariff rates, associated with the 2004 EU enlargement, increases the gross exports between bilateral partners on average by 14.6%. As for the value-added trade, a one percentage point decrease in the tariff rates increases the value-added trade by approximately 12%. By construction, the difference between these two numbers (2.6%) roughly corresponds to the estimated effect of tariff changes on RVAX. In a more robust specification, we document that, on average, regions facing one percentage point tariff reduction experienced a 3.2% decline in the RVAX ratio. In other words, after the 2004 EU enlargement, regions more exposed to tariff cuts increased their bilateral production linkages compared to other regions in the EU. We also provide empirical evidence that NMS and EU15 regions were affected differently by the enlargement. In particular, the RVAX ratio decreases more for NMS regions on average than for EU15 regions.

We also trace out the adjustment dynamics of trade liberalization. Specifically, we compare the evolution of the RVAX ratio in regions that experienced large tariff reductions to those regions that experienced smaller tariff declines during the pre and post-liberalization periods. Interestingly, we find that the effect of the tariff reduction, followed by the 2004 EU enlargement, grew over time. Hence, regions facing the larger tariff cuts continued expanding their cross-border production sharing even after the concurrent year.

This chapter is related to the recent empirical literature on the decomposition of bilateral trade flows into value-added components (Johnson and Noguera, 2012; Koopman et al., 2014; Borin and Mancini, 2019; Antràs and Chor, 2022). Starting with the seminal work of Johnson and Noguera (2012), these studies have made a key contribution in decomposing trade flows into several components that mirror the country's participation in GVCs. Compared to these papers, the key advantage of our work is to account for regional differences within the countries regarding their participation in regional supply chains and their adjustment to trade shocks.

We also contribute to gravity equation literature studying the economic consequences of European integration. Mayer et al. (2019) study the trade creation effect of the EU. According to the authors, the introduction of the single market in the EU increased trade between member states by 109% and welfare gains from the EU trade integration reached an average of 4.4%. Felbermayr et al. (2022) argues that welfare losses related to the EU disintegration could be as high as 23%. We depart from these studies by incorporating the regional dimensions into the EU integration process and show that the 2004 EU enlargement increased the regional production linkages.

Finally, our study links with the papers which use quantitative trade models with input-output linkages to estimate the effects of the regional free trade agreements (Caliendo and Parro, 2015). Antràs and de Gortari (2020) provide both partial and general equilibrium frameworks to study the role and scope of trade policies in shaping the location of production in value chains. A particularly relevant paper in this direction is Aichele and Heiland (2018), where authors derive a structural equation for the VAX ratio and study the effect of China's accession to the World Trade Organization (WTO). In contrast to Aichele and Heiland's (2018) work, we quantify the regional effects of one of the biggest enlargements of the EU.

The rest of the chapter proceeds as follows. In Section 2.3, we outline the process of the EU enlargement in 2004. Section 2.4 and 2.5 describes the data we use and the procedure to compute the RVAX ratio. In section 2.6, we provide descriptive statistics. Section 2.7 and 2.8 present the empirical strategy and discuss the main findings. Section 2.10 finally concludes the chapter.

2.3 The 2004 enlargement of the EU

In this section, we introduce the background information of the EU's enlargement in 2004 and motivate the importance of studying its impacts. The 2004 enlargement of the EU provides an excellent setting to study the production fragmentation effects of changes in trade liberalization. This multi-bilateral trade liberalization featured large declines in average tariff cuts and involved substantial variation in trade barriers across industries and regions.

On May 1, 2004, 10 central and eastern European countries officially joined the EU, raising the number of member states to 25. The ten new member states were Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, and Slovenia. On January 1, 2007, the EU admitted two more new members, Bulgaria and Romania, thus completing the fifth enlargement of the EU. The 2004 EU enlargements not only increased the size and population of the EU but also put an end to the East-West division of the European countries after World War II. Therefore, the 2004 enlargement of the EU has profound political and long-lasting economic implications.

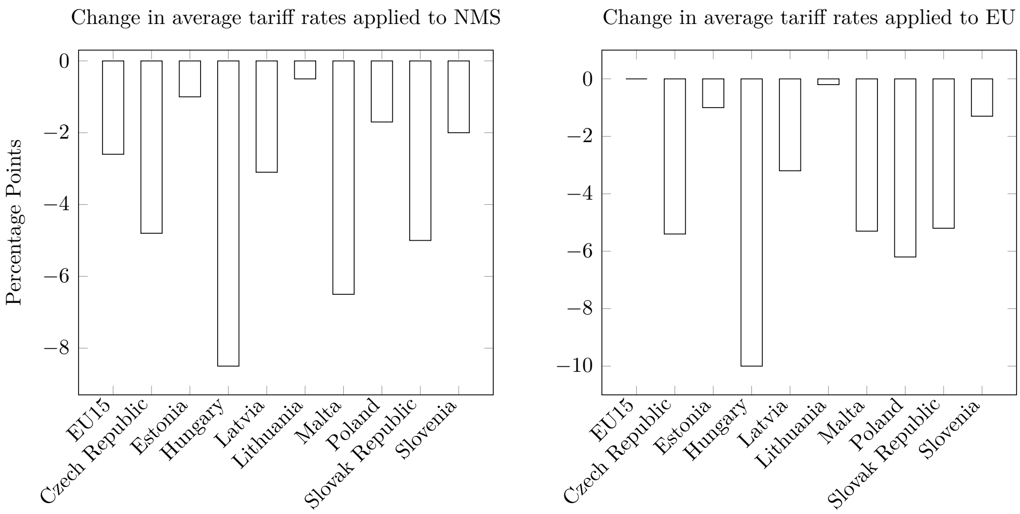
After the eastward enlargement of the EU, the world's one of the largest single markets has been formed, implementing unified tariffs both internally and externally. The EU Customs Union is one of the important components of the EU's trade policy. It refers to the complete abolition of tariffs and quantitative restrictions in trade among member states so that goods and services can flow freely among member countries. In addition, the member states also stipulate a unified restriction policy on imports from non-member countries. The goods outside the customs union will be subject to the same tariffs regardless of which member state they enter the union. As a result, the fifth expansion of the EU has significantly changed the trade rules between new and old EU members and between new EU members and third-party countries. Fig. 2.1 displays the average tariff changes between the EU15 member and NMS from 2003 to 2004. Before the trade liberalization in 2003, the average tariff rate of NMS applied to EU15 was approximately 4.8%. At the same time, the EU15's tariff rate towards the NMS was about 3.8%. In addition, NMS states set an average 4.3% tariff rate between one another. After the 2004 EU enlargement, tariff rates between the EU and NMS became zero.

2.4 Data

To study the effect of trade liberalization on production fragmentation, we use the EU regional input-output (EUREGIO) table constructed by Thissen et al. (2018). The EUREGIO database contains input-output (I-O) tables for 249 EU NUTS2 regions and 16 non-EU countries from 2000 to 2010. Each I-O table provides information on intermediate and final consumption for 16 tradeable industries[3]. Compared to other I-O tables, such as WIOD or the OECD Input-Output Databases, the key advantage of using the EUREGIO database in our analysis is that it provides regional information on final and intermediate goods trade, which enables us to capture the effects of trade liberalization

[3] All the NUTS2 regions, non-EU countries and economic sectors included in the EUREGIO database are listed in the Appendix 2.A.1

Figure 2.1: Change in the average tariff rates between EU15 and NMS after the 2004 EU enlragment



Note: Fig. 1 displays the changes in average effectively applied tariff rates from 2003 to 2004, followed by the 2004 EU enlargement. Source: World Integrated Trade Solution. Own Calculations

on production fragmentation on a more granular level than national borders within the EU. Throughout the analysis, we limit our sample to manufacturing sectors, as the national bilateral tariff rates data are only available for these industries.

Data on bilateral tariffs at the country level are retrieved from World Integrated Trade Solution (WITS) at the 2-digit ISIC Rev. 3 industry level. We use the effectively applied bilateral tariff rates, the lowest available tariffs set among the partner countries. The primary data source for regional labour markets is the Structural Business Statistics (SBS) provided by EUROSTAT. The SBS dataset provides sectoral information on employment for each European NUTS 2 region. The main advantage of using the SBS data is to have detailed employment data on NACE Rev. 2 economic activities, which can be easily merged with tariff data using the UN statistics division's correspondence tables.

2.5 Computing regional VAX ratio

In this section, we follow Johnson and Noguera (2012) to measure the production fragmentation across regions by deriving the regional value-added to gross exports ratio (RVAX). First, we calculate each region's value-added exports, which are ultimately absorbed into destination markets. Afterwards, we take the value-added to gross exports ratio (RVAX) as an inverse measure of production fragmentation.

Consider a world with $i \in R$ regions and $s \in S$ sectors. Output in each region is produced by combining the local factors (such as labour and capital) and intermediates produced domestically or outsourced from other regions. Output produced in each region can be used as an intermediate or final consumption on domestic or on foreign markets. The market clearing condition for the gross output for each region in sector s can be written as follows:

$$y_i(s) = \sum_j f_{ij}(s) + \sum_j \sum_s z_{ij}(s) \tag{2.1}$$

where $y_i(s)$ corresponds to the value of the output of region i in sector s, f_{ij} and $z_{ij}(s)$ are exports of final and intermediate goods from region i to region j in sector s. We characterize the input-output structure of the world's economy using the block matrix notations:

$$\mathbf{Y} = [\mathbf{I} - \mathbf{A}]^{-\mathbf{1}}\mathbf{F} \tag{2.2}$$

Here, $\mathbf{Y}$ and $\mathbf{F}$ are the $RS \times 1$ vectors of gross output and final consumption, respectively. $[\mathbf{I} - \mathbf{A}]^{-\mathbf{1}}$ denotes the Leontief inverse where $\mathbf{I}$ is $RS \times RS$ identity matrix, and $\mathbf{A}$ corresponds the matrix of direct requirement coefficients with the same dimensions as $\mathbf{I}$. Using the Eq. (2.2) we can compute:

$$\mathbf{RVA} = \hat{\mathbf{V}}\hat{\mathbf{Y}}[\mathbf{I} - \mathbf{A}]^{-\mathbf{1}}\mathbf{F_j} \tag{2.3}$$

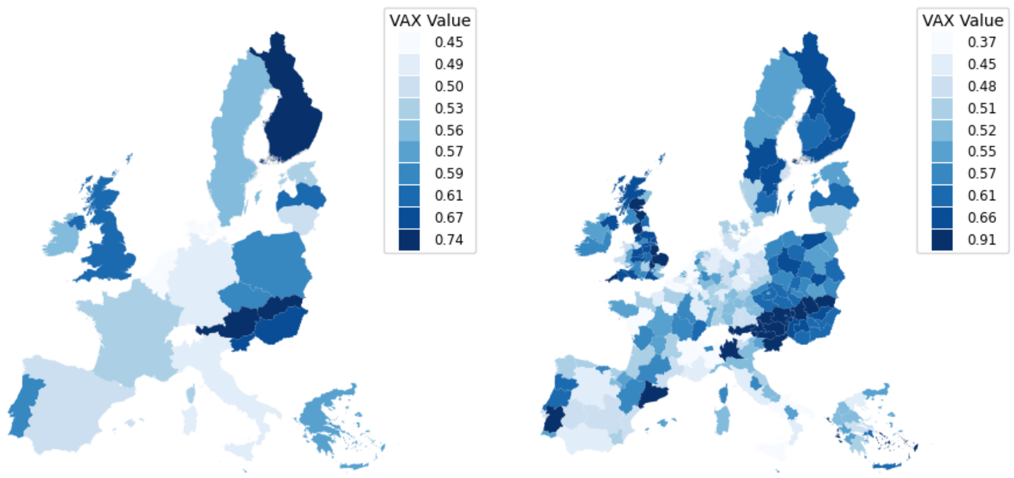
where $\hat{\mathbf{V}}$ and $\hat{\mathbf{Y}}$ are the $RS \times RS$ diagonal matrices with value-added and gross output entries. Each element of the RVA matrix entry in Eq. (2.3) corresponds to the value-added exports originating from region i, industry s

that is ultimately absorbed in the region j. Using Eq. (2.1), we can easily compute a region i's gross exports to region j in sector s by summing the exports of final and intermediate goods: $GX_{ij} = f_{ij}(s) + z_{ij}(s)$. Element-wise division of RVA (where $i \neq j$) to GX_{ij} yields the value-added to gross exports ratio (RVAX). Similar to Johnson and Noguera (2012), the RVAX captures the regional production-sharing patterns between the bilateral partners. In other words, if, due to the exogenous trade shock, the value of gross exports exceeds the amount of value-added exports, it can only be explained by the region's increased indirect export intensity through the value chains. Therefore, It is easily verified that a lower RVAX ratio is associated with higher regional engagement in cross-border production chains.

2.6 Descriptive statistics

Using the data and the framework already discussed, we document the two stylized facts regarding the EU regions' participation in production sharing.

Figure 2.2: VAX ratio across EU countries and regions in 2007



(a) VAX ratio for EU24 countries **(b)** RVAX ratio for EU249 regions

This figure plot the value-added to gross exports ratio separately for the EU countries (left map) and NUTS2 regions (right map). Some of the overseas EU territories are excluded from the map. Own Calculations

Using Eq. (2.3) we calculate the value-added exports for each bilateral pair in our data. By Summing all industries s and all destinations, where $i \neq j$, we obtain the region $i's$ aggregate value-added exports (RVA_i), which are absorbed in all other destinations. With the same principle, we calculate each region's gross exports GX_i. Dividing RVA_i to GX_i, we then compute the aggregate value added to gross exports ratio ($RVAX_i$) for each region. We also compute the country-level VAX ratio by taking the simple averages of $RVAX_i$ for each member state of the EU. Fig. 2.2 plots the obtained results for the EU in 2007. The left-hand side map shows the average VAX values for the EU24 countries. At the same time, Fig. 2.2a visualizes the spatial distribution of RVAX for the EU regions[4]. The darker colour indicates the higher value added to gross exports ratio, which translates into regions' (countries') less participation in the regional value chains.

According to Fig. 2.2, the RVAX ratio exhibits substantial heterogeneity within the EU compared to the country level. For example, the average VAX ratio for Germany in 2007 was approximately 0.49. While we observe the varying RVAX ratio for german regions, starting from 0.41 and reaching as high as 0.56 in 2007.

Next, we exploit the time series structure of our data and compare the changes in the gross and value-added exports during the ten-year period within the EU. Using Eq. (2.3), we compute the value-added and gross exports (imports) of the EU to (from) Non-Member states. Fig. 2.3 plots the changes in gross and value-added trade of the EU to NMS from 2000 to 2010[5]. At first glance, it is clear that trade (both in gross and value-added) from the EU to NMS has increased over time. Yet, the gap between gross and value-added trade has widened during these years. The divergence between gross and value-added trade indicates that, on average, the production linkages between the bilateral partners have increased over time.

2.7 Empirical approach

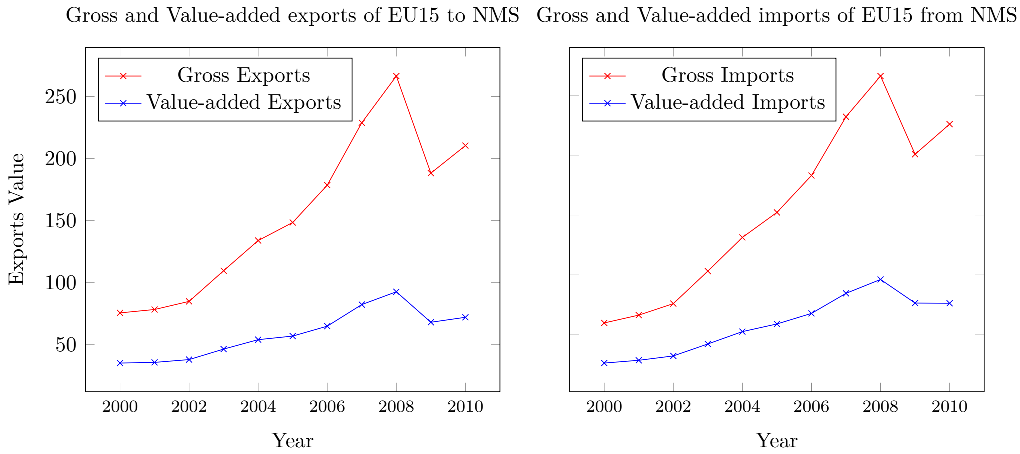
In this section, we quantify the effect of the EU 2004 enlargement on gross exports (X_{ijt}), value-added exports (RVA_{ijt}) and value-added to gross exports

[4]In appendix 2.A.5, we also document the spatial distribution of (R)VAX values for 2003, which is the pre-liberalization period in our sample

[5]We also plot the trade between NMS in appendix 2.A.6

($RVAX_{ijt}$) ratio at the regional level.

Figure 2.3: Gross and value-added exports (imports) of EU15 to (from) NMS



Note: Fig. 2 displays the gross and value-added exports/imports of EU15 to/from NMS from the years 2000-2010. Source: World Input-Output database. Own Calculations

2.7.1 Baseline model

Our empirical approach is similar to Topalova (2010) and Dix-Carneiro and Kovak (2017), studying the local effects of trade liberalization. In our baseline specification, we use gravity-style regressions to examine whether regions that face lower tariff-equivalent prices experience higher exports and value-added but lower $RVAX$:

$$\ln{(y_{ijt})} = \alpha + \beta RWT_{ijt} + \Gamma \mathbf{X}_{ij} + \delta_{it} + \delta_{jt} + \varepsilon_{ijt} \tag{2.4}$$

The sample period for the regional analysis is 2000 to 2008. The dependent variable, $y_{ijt} \in \{X_{ijt}, RVA_{ijt}, RVAX_{ijt}\}$, and δ_{it}, δ_{jt} and α indicate origin-year and destination-year fixed effects and the constant. We control for other proxies of bilateral trade frictions such as distance, country dummy and border dummy. β is the main coefficient of interest. Following the literature (Topalova, 2010; Caliendo and Parro, 2022), we construct the variable RWT_{ijt} (Regional

Weighted Tariff) as follows:

$$RWT_{ijt} = \frac{\sum_k \text{Employment}_{\ jk,2000} \ln(1+\tau_{ijkt})}{\text{Total Employment}_{\ j,2000}} \tag{2.5}$$

Here, τ_{ijkt} is the national tariff rate in industry k that region j applies on region i at year t[6]. Eq. (2.5) is a weighted average of these tariffs across tradable industries, with more weights on industries capturing more regional employment in the base year 2000. Thus, although all regions face the same vector of tariff reduction, differences in the regional industry composition generate regional variation in trade shocks. As already noted by Topalova (2010), the point estimate β in Eq. (2.4) does not identify the absolute impact of the EU enlargement on regional production sharing. Instead, it measures the relative effect of whether some EU regions are affected more than others by abolishing the trade-related tariffs between EU 15 and NMS. For illustrative purposes, we plot the spatial distribution of regional weighted tariff rates for 2003 in Appendix 2.A.7. The map excludes the zero tariff rates applied within the EU15 member states. At first glance, it is clear that there is a regional variation in tariff rates applied by the EU regions in 2003. Compared to EU15 states, NMS (mainly concentrated on the top-right part of the map) impose, on average higher regional adjusted tariff rates.

To get the consistent estimate of β in Eq. (2.4), the identification assumption must hold that ϵ_{ijt} must be uncorrelated with RWT_{ijt}, conditional on the region-year fixed effects and other trade frictions. An omitted variable that drives our outcome variable and is correlated with RWT_{ijt} but is not captured by other trade friction regressors is unlikely to exist. In section 2.8, we confirm that our results are robust to various potential alternative measurements, specification choices, and confounders.

[6]Bilateral Tariff rates (τ_{ijkt}) are only available at the national level. Any tariff rates set between two regions are those set by the countries these regions belong to. Due to the simplicity, we do not introduce country-specific notations in Eq. (2.5)

2.8 Results

2.8.1 Main findings

We begin by examining the effects of trade liberalization on gross and value-added exports for the EU regions before and after the enlargement. Hence we drop extra-EU trade and respective tariff changes from our data[7].

Table 2.1: Trade liberalization and exports

	(1) Log Gross Exports	(2) Log Gross Exports	(3) Log Value-Added Exports	(4) Log Value-Added Exports
Regional Weighted Tariff	-15.351***	-14.553***	-13.110***	-11.980***
	(0.301)	(0.296)	(0.233)	(0.218)
ln distance	-1.442***	-1.147***	-1.229***	-0.918***
	(0.010)	(0.011)	(0.008)	(0.009)
Country dum.		0.540***		0.733***
		(0.023)		(0.017)
Country Border dum.		0.873***		0.621***
		(0.011)		(0.008)
Observations	492,840	492,840	492,840	492,840
R-squared	0.845	0.860	0.900	0.910
Origin×Year FE	YES	YES	YES	YES
Destination×Year FE	YES	YES	YES	YES

Standard errors are clustered at the origin-destination level. Years included 2001-2008. The units of observation are the EU NUTS2 regions. *** p<0.01, ** p<0.05, * p<0.1

Table 2.1 presents the estimated coefficient. Each column reports a version of Eq. (2.4) from the last section. Columns 1-2 examine RWT's effect on gross exports, while columns 3-4 examine the effect on value-added exports. Columns 2 and 4 add country and border dummies. All estimates for the coefficient on RWT_{ijt} are negative and significant, indicating that regions facing higher tariffs experience relative declines in gross and value-added exports. The coefficient estimate of -14.553 in column 2 implies that a region facing a

[7] We also keep our sample between 2001 - 2008. In appendix 2.A.8, we extend our analysis for the years 2001 - 2010

one percentage point decrease in tariff experiences approximately a 14.5% increase in gross exports to its trading partner. Tariff decrease is also negatively associated with value-added exports. Yet, compared to gross exports, the magnitude of the point estimate on value-added exports in column 4 is smaller in absolute values. Here we see that a one percentage point decrease in tariffs is associated with an approximately 11.9% increase in the value-added exports. In other words, we find that gross exports react more strongly to tariff reductions, followed by the 2004 EU enlargement, than value-added exports. We verify these results by plugging the regional value-added to gross exports ratio as our dependent variable in Eq. (2.4)

Table 2.2 shows the results of estimating Eq. (2.4) for RVAX. For interpretation, it worth noting that $\beta^{RVAX_{ijt}} = \beta^{VA_{ijt}} - \beta^{X_{ijt}}$ holds by construction, because $\log(RVAX_{ijt}) = \log(RVA_{ijt}) - \log(X_{ijt})$. We apply OLS estimation in columns 1 and 2, while in columns 3 and 4, we use PPML estimation as suggested by Silva and Tenreyro (2006). We find that a reduction in tariff rates lowers the regional value-added to gross exports ratio. According to column 4, the ratio falls by 3.2% when bilateral tariff rates are reduced by one percentage point.

2.8.2 Heterogeneous effects

In this section, we study the heterogenous effect of tariff changes on the value added to gross exports ratio. In particular, we partition the data into different groups based on the EU membership status. Afterwards, we estimate the effect of tariff change on the RVAX ratio for each sub-sample using Eq. (2.4). Table 2.3 shows the obtained results. For a better comparison, in column 1, we reproduce the results already presented in Table 2.2, which corresponds to the intra-EU24 trade before and after enlargement. In column 2, we estimate the effect of tariff reduction on the RVAX ratio from NMS to EU15. Here we see that a one percentage point tariff decrease is associated with a 2.5% decrease in the RVAX ratio. This effect is almost 1.1 percentage points higher than the estimated coefficient in columns (3), which corresponds to the scenario where we only include the RVAX ratio from EU15 to NMSs. In other words, the difference between these two point estimates stems from the fact that the 2004 EU enlargement increased NMSs' regional exports to EU15 along the

Table 2.2: Trade liberalization and RVAX

	(OLS) Log RVAX	(OLS) Log RVAX	(PPML) RVAX	(PPML) RVAX
Regional Weighted Tariff	2.241***	2.573***	2.778***	3.206***
	(0.119)	(0.112)	(0.156)	(0.153)
ln distance	0.213***	0.229***	0.183***	0.254***
	(0.003)	(0.003)	(0.005)	(0.006)
Country dum		0.193***		0.365***
		(0.009)		(0.018)
Country Border dum.		-0.252***		-0.246***
		(0.004)		(0.006)
Observations	492,840	492,840	492,840	492,840
R-squared	0.452	0.511		
Origin×Year FE	YES	YES	YES	YES
Destination×Year FE	YES	YES	YES	YES

Standard errors are clustered at the origin-destination level. Years included 2001 - 2008. The unit of observation is the EU NUTS2 regions. *** p<0.01, ** p<0.05, * p<0.1

value chains more than it did in the opposite case. In column 4, we see that tariff changes due to the 2004 EU enlargement also positively affect the RVAX ratio when trading partners are NMSs. Yet the estimated effect is small and statistically insignificant.

In the last columns, we fully exploit the richness of our data. In particular, we add extra-EU trade to our analysis and estimate the effect of tariff change on the value added to gross exports ratio using the full sample. It has to be noted that, in column 5, the point estimate does not identify the effect of tariff changes caused by the 2004 EU enlargement. Instead, it measures the overall changes in the RVAX ratio associated with tariff variations between EU regions and their foreign trading partners. By comparing the points estimates in columns (1) and (5), we shed light on the fact that due to the geographical proximity, tariff changes associated with the EU enlargement had a larger effect on regional production fragmentation compared to the case when we also include tariff change for all the EU bilateral partners.

Table 2.3: Heterogeneous effects of trade liberalization

	(1) Intra-EU24	(2) NMS to EU15	(3) EU15 to NMS	(4) NMS to NMS	(5) Intra/Extra - EU25
Regional Weighted Tariff	3.206***	2.519***	1.447***	0.307	0.835***
	(0.153)	(0.419)	(0.347)	(0.187)	(0.160)
ln distance	0.254***	0.201***	0.231***	0.186***	0.228***
	(0.006)	(0.007)	(0.006)	(0.007)	(0.005)
Country dum	0.365***	0.340***	0.376***	0.310***	0.341***
	(0.018)	(0.020)	(0.019)	(0.020)	(0.018)
Country Border dum.	-0.246***	-0.257***	-0.238***	-0.263***	-0.241***
	(0.006)	(0.006)	(0.006)	(0.007)	(0.005)
Observations	492,840	413,509	480,361	359,141	558,427
Origin × Time FE	YES	YES	YES	YES	YES
Destination × Time FE	YES	YES	YES	YES	YES

Standard errors are clustered at the origin-destination level. The years included 2001 - 2008. Columns (1) - (4) include within EU trade. Column (5) adds the extra EU trade *** p<0.01, ** p<0.05, * p<0.1

2.9 The dynamic effects of trade liberalization

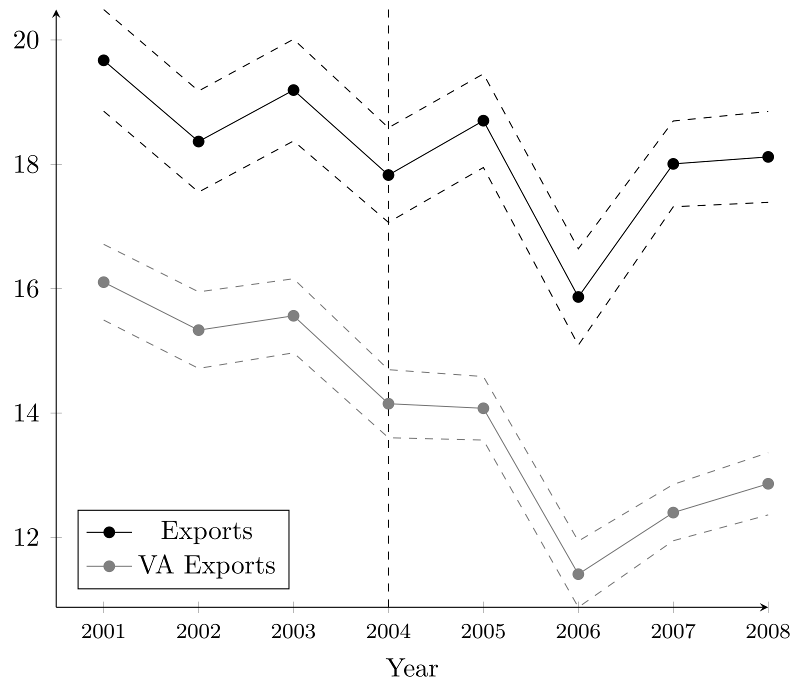
This section explores the phase-in impact of trade liberalization on the participation of the EU regions in cross-border production sharing. As highlighted by Baier and Bergstrand (2007), the institutional nature of trade liberalization provides an economic rationale for examining the adjustment dynamics. Specifically, the reduction of tariff rates might impact trade not only in the concurrent year but also in the long term. While expectations of changes in trade costs can generate anticipation effects and stimulate trade before the implementation of the free trade agreement. In order to capture the adjustment dynamics of the 2004 EU enlargement, we introduce modifications to the baseline equation Eq. (2.4)

$$ln(y_{ijt}) = \sum_{z=2001}^{2008} \theta_t 1\{z = t\} \Delta RWT_{ij} + +\Gamma \mathbf{X}_{ij} + \delta_{it} + \delta_{jt} + \varepsilon_{ijt} \qquad (2.6)$$

Similar to Eq. (2.4), in Eq. (2.6) the left-hand side variable – $y_{ijt} \in \{X_{ijt}, RVA_{ijt}, RVAX_{ijt}\}$. While the right-hand side variable, ΔRWT_{ij}, which equals $RWT_{ij,2004} - RWT_{ij,2003}$, always indicates the tariff changes that region j applies on region i after the EU enlargement in 2004. We interact ΔRWT_{ij}

with the year dummies in order to capture the adjustment dynamics of the independent variable. It is important to note that the variable ΔRWT_{ij} remains constant over time and is solely used to measure the regional tariff reduction following the 2004 EU enlargement. This strategy enables us to exploit the variation associated with trade liberalization while disregarding any tariff rates that bilateral partners imposed on each other before 2003. In contrast, the variable θ_t is time-varying with the year t. Fig. 2.4 presents the results when we estimate the Eq. (2.6) for the gross and value-added exports. It plots the coefficients of ΔRWT_{ij} (θ_t) for each year along with their 95 per cent confidence intervals. The vertical dashed line corresponds to the liberalization period, after which the bilateral tariffs between EU and non-member states became zero.

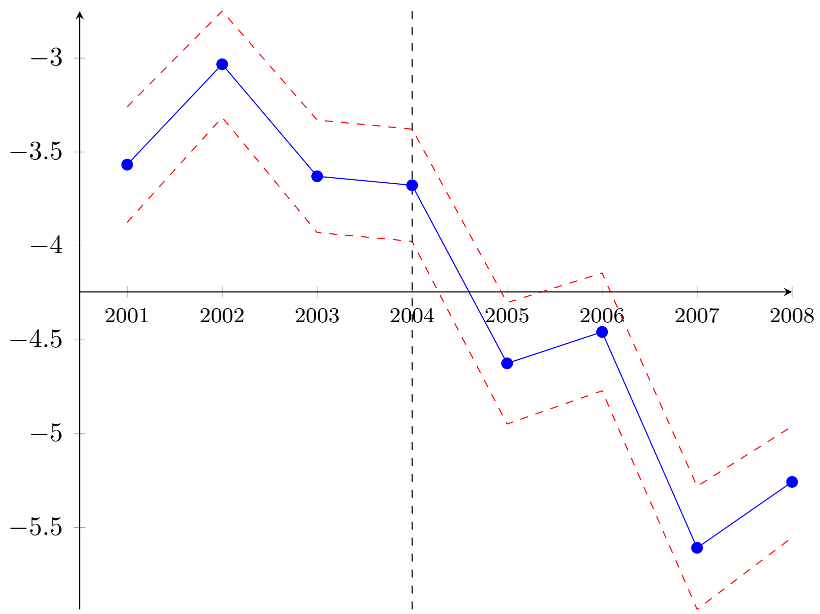
Figure 2.4: Dynamic adjustment of the EU enlargement on gross and value-added (VA) exports



Note: Each point corresponds to an individual coefficient, θ_t, in Eq. (2.6), where the dependent variable is gross and value-added exports and the independent variable is the change in regional tariff rates defined in Eq. (2.5). The dashed line shows 95 per cent confidence intervals. Standard errors are clustered at the origin-destination level.

The obtained results in Fig. 2.4 suggest that the 2004 EU enlargement had an anticipation effect, as indicated by the observed impact of tariff reduction on bilateral trade. Specifically, our analysis reveals that the highest impact of tariff reduction was observed during the pre-liberalization period (2001-2003), suggesting that regions anticipated the upcoming tariff reduction and adjusted their trade patterns accordingly. However, the effect of the 2004 EU enlargement declined more sharply in the case of value-added exports compared to gross exports. The diverging trend between the gross and value-added exports indicates that after the trade liberalization, followed by the EU enlargement, regions got more engaged into cross-border production sharing. We examine the latter hypothesis by using Eq. (2.6), where we plug the RVAX ratio as our independent variable.

Figure 2.5: Dynamic phase-in effect of the EU enlargement on RVAX



Note: Each point corresponds to an individual coefficient, θ_t, in Eq. (2.6), where the dependent variable is the RVAX ratio, and the independent variable is the change in regional tariff rates defined in Eq. (2.5). The dashed red line shows 95 per cent confidence intervals. The standard errors are clustered at the origin-destination level.

Figure 2.5 plots the coefficients of ΔRWT_{ij} (θ_t) for each year along with their 95 per cent confidence intervals. Similar to the previous figure, the vertical dashed line indicates the period of liberalization, after which bilateral tariffs between the EU and non-member states were eliminated. All estimates in Fig. 2.5 for the coefficient on RWT_{ij} are negative, suggesting that regions experiencing higher tariff reductions encounter relatively more declines in the RVAX ratio. For instance, the estimate of -3.3 in 2003 implies that a region with a one percentage point higher tariff reduction would experience a 3.3 per cent higher decline in the RVAX ratio. During the post-liberalization period, the estimated coefficient decreases at an increasing rate in absolute values, demonstrating that regions with more substantial tariff cuts undergo a faster rate of production sharing compared to regions with smaller tariff reductions. Furthermore, Fig. 2.5 indicates that the impact of the 2004 EU enlargement on the RVAX ratio appears to increase over time, suggesting the phase-in effect of tariff reduction on regional production fragmentation.

2.10 Conclusion

In this chapter, we study to what extent trade liberalization affects regional production fragmentation. Using the EU NUTS2 regional input-output data, we derive the regional value-added to gross exports (RVAX) ratio, which measures the intensity of production fragmentation of the EU regions at the bilateral level. Using the tariff variation followed by the 2004 EU enlargement, we quantify the impact of regional tariff reduction on RVAX. Our results show that a one percentage point decrease in tariff rates is associated with a 3.2% reduction in the RVAX ratio. Our findings imply that regions facing the larger tariff cuts due to the 2004 EU enlargement increased their engagement in cross-border production chains relative to other regions. Moreover, we trace out the dynamic effects of trade liberalization on production fragmentation. We find the continuing divergence in RVAX reductions in the post-liberalization period, with RVAX decline in regions facing higher tariff reductions increasing the cross-border production sharing compared to other regions.

2.A Appendix

2.A.1 Geographical coverage of European NUTS 2 regions

Figure 2.6: NUTS 2 regions covered in the EUREGIO database

2.A.2 EU regions covered in the EUREGIO database

NUTS2 Region	Country	NUTS2 Region	Country
AT11	Austria	GR22	Greece
AT12	Austria	GR23	Greece
AT13	Austria	GR24	Greece
AT21	Austria	GR25	Greece
AT22	Austria	GR30	Greece
AT31	Austria	GR41	Greece
AT32	Austria	GR42	Greece
AT33	Austria	GR43	Greece
AT34	Austria	HU10	Hungary
BE10	Belgium	HU21	Hungary
BE21	Belgium	HU22	Hungary
BE22	Belgium	HU23	Hungary
BE23	Belgium	HU31	Hungary
BE24	Belgium	HU32	Hungary
BE25	Belgium	HU33	Hungary
BE31	Belgium	IE01	Ireland
BE32	Belgium	IE02	Ireland
BE33	Belgium	ITC1	Italy
BE34	Belgium	ITC2	Italy
BE35	Belgium	ITC3	Italy
CZ01	Czech Republic	ITC4	Italy
CZ02	Czech Republic	ITD1	Italy
CZ03	Czech Republic	ITD2	Italy
CZ04	Czech Republic	ITD3	Italy
CZ05	Czech Republic	ITD4	Italy
CZ06	Czech Republic	ITD5	Italy
CZ07	Czech Republic	ITE1	Italy
CZ08	Czech Republic	ITE2	Italy

NUTS2 Region	Country	NUTS2 Region	Country
DE11	Germany	ITE3	Italy
DE12	Germany	ITE4	Italy
DE13	Germany	ITF1	Italy
DE14	Germany	ITF2	Italy
DE21	Germany	ITF3	Italy
DE22	Germany	ITF4	Italy
DE23	Germany	ITF5	Italy
DE24	Germany	ITF6	Italy
DE25	Germany	ITG1	Italy
DE26	Germany	ITG2	Italy
DE27	Germany	LT00	Lithuania
DE30	Germany	LU00	Luxembourg
DE41	Germany	LV00	Latvia
DE42	Germany	MT00	Malta
DE50	Germany	NL11	Netherlands
DE60	Germany	NL12	Netherlands
DE71	Germany	NL13	Netherlands
DE72	Germany	NL21	Netherlands
DE73	Germany	NL22	Netherlands
DE80	Germany	NL23	Netherlands
DE91	Germany	NL31	Netherlands
DE92	Germany	NL32	Netherlands
DE93	Germany	NL33	Netherlands
DE94	Germany	NL34	Netherlands
DEA1	Germany	NL41	Netherlands
DEA2	Germany	NL42	Netherlands
DEA3	Germany	PL11	Poland
DEA4	Germany	PL12	Poland
DEA5	Germany	PL21	Poland
DEB1	Germany	PL22	Poland
DEB2	Germany	PL31	Poland

NUTS2 Region	Country	NUTS2 Region	Country
DEB3	Germany	PL32	Poland
DEC0	Germany	PL33	Poland
DED1	Germany	PL34	Poland
DED2	Germany	PL41	Poland
DED3	Germany	PL42	Poland
DEE1	Germany	PL43	Poland
DEE2	Germany	PL51	Poland
DEE3	Germany	PL52	Poland
DEF0	Germany	PL61	Poland
DEG0	Germany	PL62	Poland
DK01	Denmark	PL63	Poland
DK02	Denmark	PT11	Portugal
DK03	Denmark	PT15	Portugal
EE00	Estonia	PT16	Portugal
ES11	Spain	PT17	Portugal
ES12	Spain	PT18	Portugal
ES13	Spain	SE11	Sweden
ES21	Spain	SE12	Sweden
ES22	Spain	SE21	Sweden
ES23	Spain	SE22	Sweden
ES24	Spain	SE23	Sweden
ES30	Spain	SE31	Sweden
ES41	Spain	SE32	Sweden
ES42	Spain	SE33	Sweden
ES43	Spain	SI00	Slovenia
ES51	Spain	SK01	Slovak Republic
ES52	Spain	SK02	Slovak Republic
ES53	Spain	SK03	Slovak Republic
ES61	Spain	SK04	Slovak Republic

NUTS2 Region	Country	NUTS2 Region	Country
ES62	Spain	UKC1	United Kingdom
ES63	Spain	UKC2	United Kingdom
ES64	Spain	UKD1	United Kingdom
ES70	Spain	UKD2	United Kingdom
FI13	Finland	UKD3	United Kingdom
FI18	Finland	UKD4	United Kingdom
FI19	Finland	UKD5	United Kingdom
FI1A	Finland	UKE1	United Kingdom
FI20	Finland	UKE2	United Kingdom
FR10	France	UKE3	United Kingdom
FR21	France	UKE4	United Kingdom
FR22	France	UKF1	United Kingdom
FI1A	Finland	UKE1	United Kingdom
FI20	Finland	UKE2	United Kingdom
FR10	France	UKE3	United Kingdom
FR21	France	UKE4	United Kingdom
FR22	France	UKF1	United Kingdom
FR23	France	UKF2	United Kingdom
FR24	France	UKF3	United Kingdom
FR25	France	UKG1	United Kingdom
FR26	France	UKG2	United Kingdom
FR30	France	UKG3	United Kingdom
FR41	France	UKH1	United Kingdom
FR42	France	UKH2	United Kingdom
FR43	France	UKH3	United Kingdom
FR51	France	UKI1	United Kingdom
FR52	France	UKI2	United Kingdom
FR53	France	UKJ1	United Kingdom
FR61	France	UKJ2	United Kingdom
FR62	France	UKJ3	United Kingdom
		UKN0	United Kingdom

NUTS2 Region	Country	NUTS2 Region	Country
FR63	France	UKJ4	United Kingdom
FR71	France	UKK1	United Kingdom
FR72	France	UKK2	United Kingdom
FR81	France	UKK3	United Kingdom
FR82	France	UKK4	United Kingdom
FR83	France	UKL1	United Kingdom
GR11	Greece	UKL2	United Kingdom
GR12	Greece	UKM2	United Kingdom
GR13	Greece	UKM3	United Kingdom
GR14	Greece	UKM5	United Kingdom
GR21	Greece	UKM6	United Kingdom

2.A.3 Non-EU countries covered in the EUREGIO database

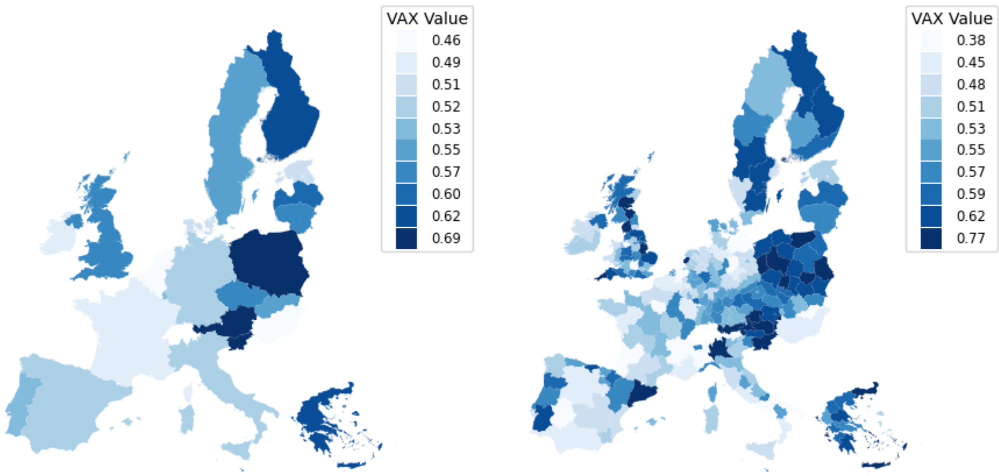
Country Code	Country Name
JPN	Japan
BRA	Brazil
AUS	Australia
MEX	Mexico
RUS	Russian Federation
BGR	Bulgaria
ROU	Romania
IND	India
IDN	Indonesia
CYP	Cyprus
CAN	Canada
CHN	China
KOR	Korea, Rep.
TUR	Turkey
USA	United States
TWN	Taiwan, China

2.A.4 Economic sectors covered in the EUREGIO database

Sector Code	Sector Name
ss1	Agriculture
ss2	Mining quarrying and energy supply
ss3	Food beverages and tobacco
ss4	Textiles and leather etc
ss5	Coke refined petroleum nuclear fuel and chemicals etc
ss6,7	Electrical and optical equipment and Transport equipment
ss8	Other manufacturing
ss9	Construction
ss10	Distribution
ss11	Hotels and restaurant
ss12	Transport storage and communication
ss13	Financial intermediation
ss14	Real estate renting and busine activitie
ss15	Non-Market Service

2.A.5 Spatial distribution of the average (regional) VAX ratio in the EU

Figure 2.7: Spatial distribution of the average (regional) VAX ratio in the EU in 2003

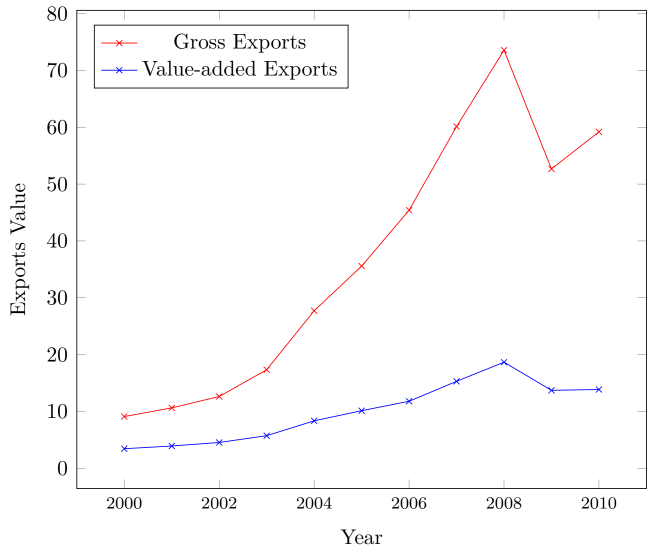


(a) VAX ratio for EU24 countries **(b)** RVAX ratio for EU249 regions

This figure plot the value-added to gross exports ratio separately for the EU countries and regions in 2003. The data EUROREGIO IO database covers 24 EU member states and 249 regions at the NUTS2 level. Some of the overseas EU territories are excluded from the map. Own Calculations

2.A.6 Trade between NMS

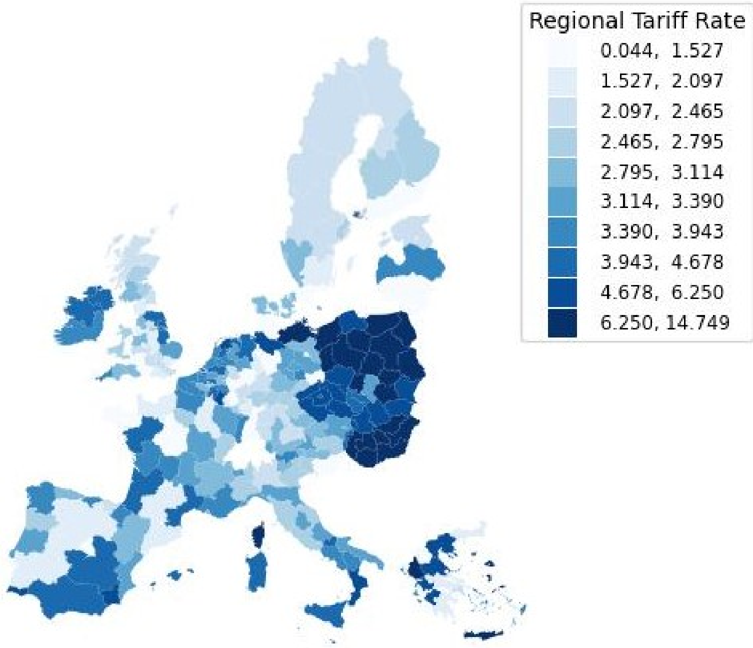
Figure 2.8: Gross and value-added exports of NMS to NMS



Note: Figure displays the Gross and Value-added exports of NMS to/from NMS from the years 2000-2010. Source: World Input-Output database. Own Calculations

2.A.7 Spatial distribution of employment weighted tariff rates in 2003

Figure 2.9: Spatial distribution of (employment adjusted) tariff rates



Note: Spatial distribution of (employment adjusted) tariff rates in EU calculated using the Eq. (2.5). Tariff data comes from the World Integrated Trade Solution. The employment data is taken from EUROSTAT's SBS database. The final data is divided into ten quantiles. Each quantile contains an equal number of observations. A darker colour represents a higher tariff ratio applied by EU15 and NMS.

2.A.8 Trade liberalization and exports within the EU, including all years

Table 2.4: Trade liberalization and exports - including all years

	(1) Log Gross Exports	(2) Log Gross Exports	(3) Log Value-Added Exports	(4) Log Value-Added Exports
Regional Weighted Tariff	-15.112***	-14.361***	-12.909***	-11.816***
	(0.300)	(0.296)	(0.233)	(0.218)
ln distance	-1.468***	-1.179***	-1.250***	-0.946***
	(0.010)	(0.011)	(0.008)	(0.009)
Country dum		0.513***		0.713***
		(0.023)		(0.017)
Country Border dum.		0.878***		0.618***
		(0.011)		(0.009)
Observations	616,088	616,088	616,088	616,088
R-squared	0.841	0.855	0.897	0.906
Origin×Year FE	YES	YES	YES	YES
Destination×Year FE	YES	YES	YES	YES

Standard errors are clustered at the origin-destination level. Years included 2001-2010. The units of observation are the EU NUTS2 regions. *** p<0.01, ** p<0.05, * p<0.1

2.A.9 Using imports shares as weights in the main specification

One of the downsides of using the regional data in our analysis is that the employment data is missing for some EU NUTS2 regions. Whenever we encounter missing values, we interpolate them with the data from the closest years. Interpolating the missing values using the data from other years are based on the assumption that employment shares are constant, at least for a short period. Violating this assumption could potentially threaten to identify unbiased estimates of trade policy change on regional production fragmentation.

Instead of using employment share, we alter our specification in Eq. (2.4) by using the import share of each industry as the weight for the year 2000. In particular, we modify Eq. (2.5) in following manner:

$$RWT^{I}_{ijt} = \frac{\sum_k \text{Import}_{\ ijk,2000} \log\left(1 + \tau_{ijkt}\right)}{\text{Total Imports}_{cj,2000}} \tag{2.7}$$

Table 2.5: Trade liberalization and RVAX - including all years

	(OLS) Log RVAX	(OLS) Log RVAX	(PPML) RVAX	(PPML) RVAX
Regional Weighted Tariff	2.203***	2.545***	2.720***	3.158***
	(0.119)	(0.112)	(0.156)	(0.152)
ln distance	0.217***	0.234***	0.192***	0.262***
	(0.003)	(0.003)	(0.005)	(0.006)
Country dum		0.200***		0.373***
		(0.009)		(0.018)
Country Border dum.		-0.260***		-0.258***
		(0.004)		(0.006)
Observations	616,088	616,088	616,088	616,088
R-squared	0.441	0.501		
Origin×Year FE	YES	YES	YES	YES
Destination×Year FE	YES	YES	YES	YES

Standard errors are clustered at the origin-destination level. Years included 2001 - 2010. The unit of observation is the EU NUTS2 regions. *** p<0.01, ** p<0.05, * p<0.1

Where the variable $Import_{ijk,2000}$ denotes the imports of the region j in sector k from region i, I$mport_{ijk,2000}$ is the total imports of the region j from the country the region i belongs to, and τ_{ijkt} again is the national tariff rate set between two countries. We plug our new regional tariff measure RWT_{ijt} in Eq. (2.4) and estimate the β coefficient using the gravity style specification.

It has to be noted that there are qualitative differences between interpreting β coefficients when using import weights compared to the case when we use employment shares in Eq. 2.4 β coefficient measures how tariff reduction affects the regions with the different sectoral compositions of employment. While using the import shares, we identified the average effect for regions that were more exposed to import competition. However, we show a high correlation between import and employment shares. We regress employment-weighted tariff rates on import-weighted tariffs controlling for time-invariant characteristics. The reported R-square is 0.97, meaning that 97% variation in employment-weighted tariffs can be explained by the variation in tariffs derived through regional import shares. In other words, regions with higher

Table 2.6: Trade liberalization and exports using import shares

	(1) Log Gross Exports	(2) Log Gross Exports	(3) Log Value-Added Exports	(4) Log Value-Added Exports
Regional Weighted Tariff	-16.639***	-16.994***	-12.956***	-12.957***
	(0.297)	(0.305)	(0.246)	(0.234)
ln distance	-1.441***	-1.134***	-1.230***	-0.909***
	(0.010)	(0.011)	(0.008)	(0.009)
Country dum		0.565***		0.754***
		(0.023)		(0.017)
Country Border dum.		0.888***		0.633***
		(0.011)		(0.008)
Observations	492,840	492,840	492,840	492,840
R-squared	0.846	0.861	0.900	0.911
Origin×Year FE	YES	YES	YES	YES
Destination×Year FE	YES	YES	YES	YES

Standard errors are clustered at the origin-destination level. Years included 2001-2008. The unit of observation is the EU NUTS2 regions. Import weights are used in all regressions as shares. *** p<0.01, ** p<0.05, * p<0.1

employment-weighted tariff rates also experience higher trade protection.

We report the new results in table 2.6 and 2.7. Compared to previous findings, the point estimates increase in absolute terms when adopting the import share as the weight. Yet the direction of the effect of trade liberalization stays the same. As shown in table 2.6 and 2.7, the results are robust, and the magnitude of the estimates is increased when adopting the import share as the weight. According to PPML estimator in 2.7 column 2, the regional value added to gross exports ratio falls by 4.347% when bilateral tariff rates are reduced by one percentage point.

Table 2.7: Trade liberalization and RVAX using import shares

	(OLS) Log RVAX	(OLS) Log RVAX	(PPML) RVAX	(PPML) RVAX
Regional Weighted Tariff	3.683***	4.037***	4.045***	4.347***
	(0.102)	(0.101)	(0.102)	(0.106)
ln distance	0.211***	0.225***	0.181***	0.250***
	(0.003)	(0.003)	(0.005)	(0.006)
Country dum		0.189***		0.360***
		(0.009)		(0.018)
Country Border dum.		-0.255***		-0.249***
		(0.004)		(0.006)
Observations	492,840	492,840	492,840	492,840
R-squared	0.455	0.514		
Origin×Year FE	YES	YES	YES	YES
Destination×Year FE	YES	YES	YES	YES

Standard errors are clustered at the origin-destination level. Years included 2001-2008. The unit of observation is the EU NUTS2 regions. Import weights are used in all regressions as shares. *** p<0.01, ** p<0.05, * p<0.1

CHAPTER 3

Empirics of the central place property using islands data

3.1 Publication details

Paper III (Chapter 3):

Empirics of the central place property using islands data

Author(s):

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Abstract:

This chapter tests the main prediction of Christaller's central place property (CPP), which postulates that smaller cities can always be found between larger cities. By collecting the data on populated volcanic islands, the spatial distribution of economic activity is matched to the key assumption of the CCP, which dictates that all economic activity has to take place either on a line or on a circle. The urban areas on each island are identified using the Open Street Map's building data. The findings demonstrate that, on average, 70% of the size distribution of the neighbouring urban areas follows the spatial pattern predicted by the CPP. The size distribution of urban areas in the data is then compared to the counterfactual counterpart obtained by randomizing the location of the cities on each island. A simple one-tailed statistical test reveals that the observed and counterfactual size distributions of the cities in the data are significantly different.

Publication details:

Working paper.

3.2 Introduction

This chapter tests the main prediction of Christaller's (1933) central place property (CPP), according to which the smaller city can always be found between two larger cities. By collecting the data on populated volcanic islands, the spatial distribution of economic activity is matched to the key assumption of CCP, as per which all economic activity has to take place either on a line or on a circle. The urban areas are detected on each island using the unsupervised machine learning algorithm and Open Street Map's building data. The results indicate that, on average, 70% of the size distribution of the neighbouring cities follows the spatial pattern predicted by CPP. Moreover, the counterfactual size distribution of cities is obtained by randomizing the locations of urban areas on each island. The simple one-tailed z-test shows that the observed and counterfactual city size distributions are significantly different from each other.

According to Christaller's (1933) central place theory, city size distribution follows the hierarchical pattern. The larger cities are characterized by hosting a wide range of industries, whereas smaller cities are limited to offering only a subset of the industries presented in the larger cities. Such a type of hierarchical ordering of cities' is sometimes referred to *hierarchy property* of central place theory (Hsu, 2012). The size differentiation of the cities leads to another key prediction of the theory, known as the *central place property (CPP)*, which states that smaller cities can always be found between larger cities. Christaller's (1933) central place theory has been a workhorse theoretical model in the urban and regional economics literature to study the size and the location of the cities (Fujita and Krugman, 1995; Tabuchi and Thisse, 2011; Hsu, 2012). While modelling the central place theory, the literature frequently assumes a simplified geography, where all economic activity occurs either on a line or on a circle. This stylized assumption is made to ensure the tractability of the models, and more importantly, comparative static exercises can be obtained analytically (Proost and Thisse, 2019). Nevertheless, making testable predictions from the central place models can be challenging, as the observed distribution of economic activity often deviates from the stylized assumptions commonly present in the literature. In light of these considerations, this chapter conducts an empirical analysis to determine to which extent the theoretical predictions of the CPP hold when observing the city size distribution on simplified geography.

Inspired by the key assumption of the CPP, according to which all economic activity has to take place either on a line or on a circle, this chapter constructs a unique dataset from the global islands database assembled by Sayre et al. (2019). The global islands database includes geospatial vector data of all the islands on the globe, allowing for an empirical examination of the CPP. In particular, this study focuses on 84 oval-shaped islands where economic activity is only distributed along the coastal region due to their volcanic geography. The identification of the urban areas was conducted using the Open Street Map's (OSM) publicly available building data. The resulting data set consists of the geolocation of residential and non-residential buildings and the road network of each island. By using the constructed data, the empirical distribution of economic activity is matched to the stylized assumptions commonly found in the CPP literature, enabling an empirical evaluation of the CPP.

Following Campello et al. (2013), this study employs a hierarchical density-based clustering algorithm, HDBSCAN, to delineate the urban areas on each island in the sample. The HDBSCAN algorithm groups buildings on each island that are closely packed together, defined as buildings with many nearby neighbours, while marking other buildings as outliers located in low-density areas. Using the HDBSCAN algorithm presents two distinct advantages. Firstly, the algorithm exogenously determines the size and the number of urban areas on each island. Secondly, the algorithm does not require auxiliary geographies or satellite imagery, which is often used to detect urban areas in different countries (e.g., Duranton, 2015; Baragwanath et al., 2021). Once the urban areas are delineated in the sample, Edelsbrunner et al.'s (1983) α-shape algorithm draws the surrounding boundaries for each detected urban area on the island.

To assess the extent to which CPP holds in the data, a simple iterative algorithm is developed that calculates the average share of neighbouring cities satisfying the CPP configuration. The algorithm first randomly selects an urban area and its two closest neighbours and determines whether they form a triplet that meets the CPP criteria. The iteration continues until all possible triplets have been checked on each island. The final result is the average share of triplets satisfying the CPP configuration, which is found to be approximately 70% in the data. In other words, on average, 70% of neighbouring cities in the data follow the spatial pattern predicted by CPP. Moreover, the distribution of the average share of CPP in the data is positively skewed. After filtering the data from ten outlier observations, the average CPP share becomes 74%. The obtained results are compared to the counterfactual counterparts, which are derived by randomising the locations of urban areas on each island. This chapter finds that the observed average CPP share is always higher than its counterfactual equivalent. A simple one-sided statistical test rejects their equality at the five per cent level of significance. These results suggest that the observed spatial distribution of urban areas in the data is not due to chance but is instead driven by the economic forces usually micro-founded in the theoretical literature.

This study offers three key contributions to the existing literature. Firstly, it provides a novel and publicly accessible geospatial data set of islands where the economic activity is confined to the coastal regions. Most islands in the dataset are volcanic, providing a natural explanation for the unoccupied hinterlands. The data set is used to empirically test the central place property as predicted by Christaller (1933). Yet, it can also be utilized to validate other theoretical results obtained from spatial competition models that often assume a simplified geography, where economic activity occurs either on a line or a circle.

Secondly, this chapter contributes to the theoretical and empirical literature exploring Christaller (1933) central place theory. An earlier study by Fujita et al. (1999) provided the theoretical explanation for the emergence of the hierarchical urban system in the spirit of Christaller (1933). In their paper, the authors showed that the equilibrium distribution of urban industries is achieved through the interplay of scale economies and immobile agricultural workers. Traditional agglomeration-dispersion forces ensure the creation of the hierarchical ordering of cities, where bigger cities will host a wider range of industries compared to the smaller cities. Using Fujita et al.'s (1999) framework, Tabuchi and Thisse (2011) analyse the importance of internal trade costs in the emergence of central places. A particularly relevant paper is Hsu (2012), where the author provides the microeconomic underpinnings of the CPP. The author argues that firms with higher production fixed costs will only be found in larger cities, generating the hierarchical structure in which smaller cities are situated between larger neighbouring cities. This chapter can be regarded as the empirical evidence supporting Hsu's (2012) theoretical results.

Given the recent development in theoretical contributions of the central place theory, the empirical literature also contributed to showing the existence of the hierarchical sorting of industries across several countries. Mori et al.'s (2020) develop the simple algorithm which detects the central places and provide the empirical evidence that hierarchy property holds for Japan, Germany, France, India, China, and the United States. Mori and Wrona (2021) combine this algorithm with the structural gravity equation to show that the large cities excessively export to their hinterlands. Handbury and Weinstein (2015) find that big cities offer consumers a much more extensive array of available goods. While much of the empirical literature has focused on studying the hierarchical industry distribution in urban systems, this chapter takes a unique approach by demonstrating the city size distribution while maintaining the simplified geographical setting commonly assumed in the theoretical literature. To the best of the author's knowledge, this study is the first attempt to empirically formalize the central place property.

Thirdly, this article adds to the growing body of literature that delineates the urban areas in developing countries (see Duranton, 2021, for an overview). Most of the studies usually use either commuting flows or satellite imagery (e.g., Duranton, 2015; Dingel et al., 2021; Baragwanath et al., 2021; Bosker et al., 2021) in order to detect urban areas in different developing countries. However, owing to limitations in the available data for the selected islands, this study adopts the approach proposed by Arribas-Bel et al. (2021), which utilizes data on buildings to delineate urban areas in Spain through the application of a density-based spatial clustering algorithm. Using a similar methodology and equipped with the Open Street Map's building data, this chapter demonstrates that urban areas can be detected on remote territories where commuting flows or satellite imagery are unavailable.

The remainder of this chapter is structured as follows. Section 2 provides the background for constructing the final data sets. Section 3 describes the methodology used to delineate the urban areas on each island. Section 4 presents the results, and the final section concludes.

3.3 Data

In order to accurately validate the CPP's main prediction, it is necessary to create a unique data set that aligns with the key assumption of the central place property, according to which all economic activity must occur either on a line or on a circle. This section outlines the steps involved in the construction of the final dataset, which will be employed in the subsequent analysis.

This study uses the Global Islands Database, commissioned by the Group on Earth Observations (GEO) and constructed by Sayre et al. (2019). The database comprises geospatial vector data of all the islands in the world, with information on the size and boundaries of approximately 350,000 islands, mapped using a 30-m spatial resolution global shoreline vector obtained from 2014 Landsat satellite imagery. Three different size classes of islands are distinguished in the database: continental mainlands, islands greater than one km^2 (21,818) and islands smaller than one km^2 (318,868). For this study, the continental mainlands and islands smaller than one km^2 were dropped from the database. Those islands are either too big to be suitable for the analysis or too small to have any economic activity. Using the publicly available Open Street Map's building data, the remaining islands were checked on the map manually. In total, 84 oval-shaped islands were identified, where economic activities are distributed along the coastline, mostly being volcanic with the uninhabited hinterland. A complete list of these selected islands can be found in Appendix 3.A.1.

The obtained data set is complemented by the accurate geolocation of buildings and street networks retrieved from the Open Street Map via OSMnx package created by Boeing (2017) using Python Programming Language. The geolocation of buildings and street networks serves as a proxy for economic activity and is used to detect urban areas on each island. The following section describes the machine learning algorithm which detects the urban areas using the density of buildings on each island.

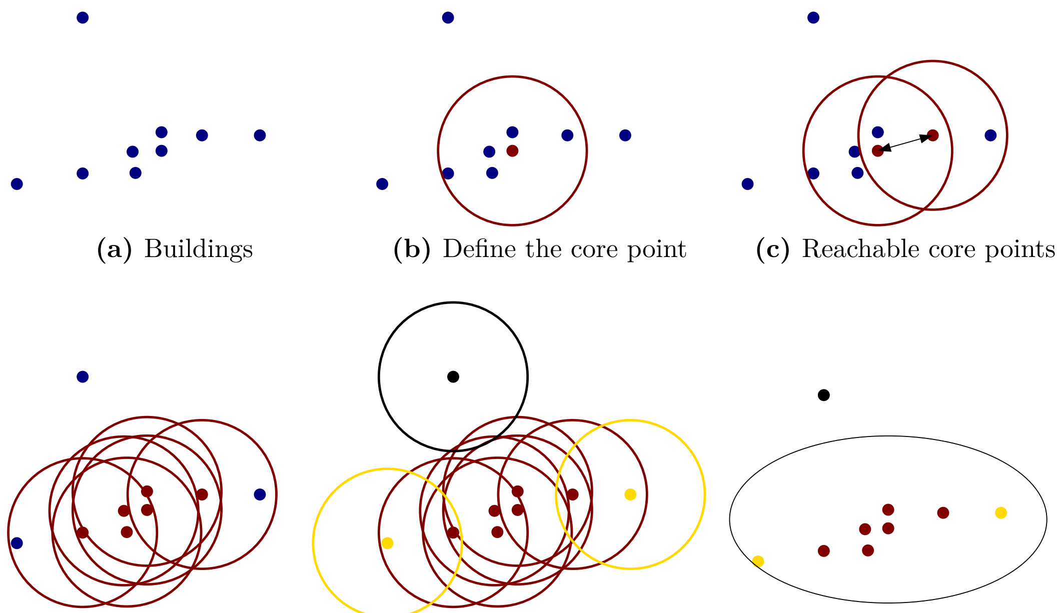
3.4 Delineating urban areas

This chapter follows the recent literature see (see Bellefon et al., 2021; Arribas-Bel et al., 2021), which uses detailed information on buildings' locations to detect the urban areas in France and Spain. Similar to Arribas-Bel et al. (2021), this chapter uses the density-based spatial clustering algorithm or, shortly, DBSCAN, initially developed by (Ester et al., 1996). The key advantage of the DBSCAN compare to other clustering algorithms is that it does not partition the data. Instead, the DBSCAN algorithm detects the dense cluster while leaving the sparse background as noise. As a result, not every point is assigned to the cluster, and the number of clusters is unknown beforehand.

In order to implement the DBSCAN algorithm properly, two input parameters are required to indicate in advance. First is the *maximum distance parameter*, which defines the maximum distance between two points (or buildings) to be considered in the same neighbourhood. This parameter defines the size of the neighbourhood around a data point. The second is the *minimum sample size*, which defines the minimum number of buildings in an urban area to be considered a dense region. Fig. 3.1 demonstrates the basic logic of the DBSCAN algorithm. For simplicity, the minimum sample size and distance parameter are equal to 4 and 1, respectively. Given the random points/buildings in Fig. 3.1a the algorithm chooses the observation and draws the circle around it (Fig. 3.1b). The radius of the circle is the distance parameter specified beforehand. In this simplest example, the algorithm classifies the point as the core point, as it meets the minimum sample criteria - having at least four observations within the circle centred at the red point.

In Fig. 3.1c, the algorithm draws a circle from another point and searches for the core points using the same logic described above. In Fig. 3.1c, two red points will be considered to belong to the same cluster, as they are both located in the area where the circles overlap. In other words, those points are mutually reachable and indicated by the double-headed arrow. In Fig. 3.1d, the algorithm defined all the core points in the data, shown in red colour. Two yellow points in Fig. 3.1e are called boundary points, as they do not meet the minimum sample criteria, yet they are reachable to one of the core points in the data. The observation in the black colour neither meets the parameter restrictions nor has the reachable core point within its own circle. As a result,

Figure 3.1: An example of DBSCAN algorithm.



(a) Buildings **(b)** Define the core point **(c)** Reachable core points

(d) Detecting the core points **(e)** Noise and Boundary Points **(f)** Delineated Urban Areas

Note: This figure provides an example of the DBSCAN algorithm. The minimum sample size is equal to 4. The maximum distance is equal to 1, which is also a radius of circles. Blue points in (a) are the observations on which the DBSCAN is applied. (f) shows the final results, where the red and the yellow points are considered as a cluster. The black dot is the noise in the data.

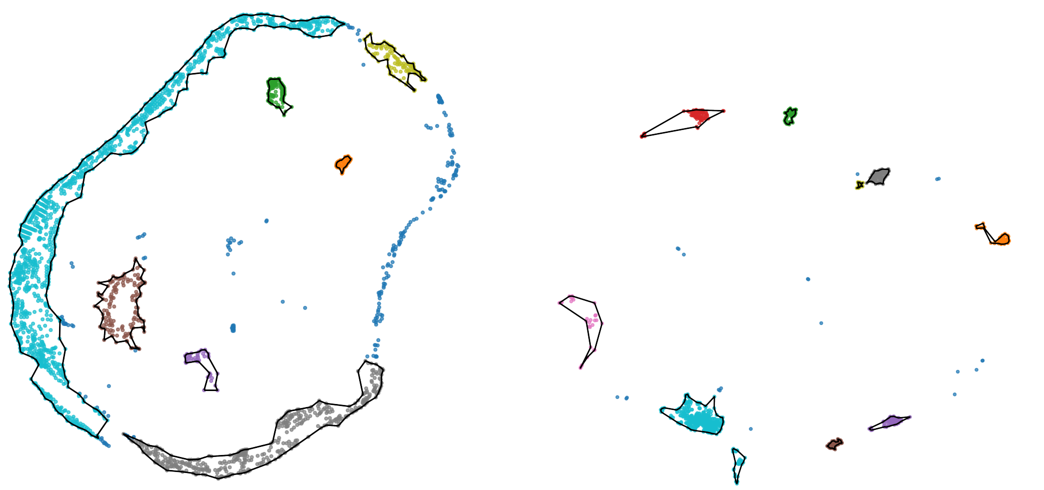
the algorithm considers this point as noise. Fig 3.1f presents the outcome of DBSCAN. The delineated urban area consists of a union of core and boundary points. Those observations are directly or indirectly reachable to each other or satisfy parameter conditions specified before.

One of the key issues in using the DBSCAN algorithm is its sensitivity to the maximum distance parameter. This parameter plays a crucial role in determining the size of the urban areas and is typically chosen based on statistical information. For example, in their study, Arribas-Bel et al. (2021) utilized Spanish commuting statistics to set the maximum distance parameter at 2,000 meters. However, the remote nature of most of the islands in the data set presents difficulty in obtaining the necessary statistical information and then deriving the maximum distance parameter for each island individually. To overcome this challenge, this chapter adopts the Hierarchical Density-Based Spatial Clustering of Applications with Noise (HDBSCAN), developed by Campello et al. (2013). Unlike DBSCAN, HDBSCAN eliminates the need for a maximum distance parameter and solely relies on a minimum sample size as the only input parameter for the algorithm.

The HDBSCAN algorithm is applied in the final data set to detect urban areas. The minimum sample size is set to be equal to 1.5% of the total number of buildings on each island. The choice of the minimum sample size can be arbitrary as well. However, as pointed out by McInnes et al. (2017), the algorithm is less sensitive to the minimum sample size compared to the maximum distance parameter. Additionally, the minimum sample size set for each island roughly corresponds to the percentage share of buildings Arribas-Bel et al. (2021) use in their application. Once the urban areas are identified, the α-shape algorithm proposed by Edelsbrunner et al. (1983) is utilized to construct the boundaries of each cluster. Fig. 3.2 illustrates the results on two selected islands, Nauru and Lakeba. Contrasting colours represent the different urban areas on each island. The surrounding black lines for each cluster correspond to the boundary of each region. The noisy data, represented as blue points on the map, is not subject to the application of the alpha-shape algorithm.

From the example presented in Fig. 3.2, it becomes clear how the empirical distribution of economic activities is mapped to the simple geography usually presented in the theoretical papers on central places (Hsu, 2012; Tabuchi and Thisse, 2011). Similar to these theories, the spatial structure in the constructed data set is also very simple. Most of the buildings on each island are distributed along the coastal regions, leading to the concentration of economic activity on a circle, as usually assumed by the central place property.

Figure 3.2: Delineated urban areas on Nauru and Lakeba islands



(a) Nauru **(b)** Lakeba Island

Note: Delineated Urban areas on Nauru (left map) and Lakeba Island (right map) using HDBSCAN algorithm. Contrasting colours represent the different urban areas. The alpha shape algorithm defines the boundaries of each urban area. Non-bounded buildings are the noisy (blue) points in the data.

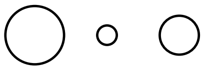
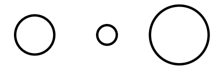
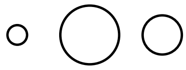
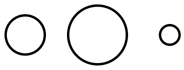
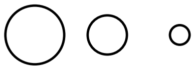
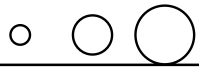
3.5 Identifying the central place property

To identify the central place property, this chapter develops a simple iterative algorithm. The proposed algorithm randomly selects an urban area and its two closest neighbours, forming a triplet of closely located settlements[1]. In order to accurately determine the three neighbouring urban areas, the algorithm uses the information on the street network and calculates the distance matrices between the settlement's centroids. Afterwards, the algorithm determines whether the triplet adheres to the central place property (CPP) configuration. Through the simple permutation, it is evident that there are a maximum of six possible combinations of the location of urban areas within each triplet, as shown in Table 3.1. Out of the six possible combinations depicted in the

[1]From now on, the terms urban areas and settlements will be treated as synonymous and used interchangeably.

second column of Table 3.1, only combinations 1 to 4 meet the CPP criteria. These are the cases where the smallest settlement is between two larger urban areas or the largest urban area is among the neighbours of two smaller settlements. It should be noted that the size of urban areas on each island is unique, resulting in non-uniformly sized urban areas within the triplet.

Table 3.1: Identifying the central place property

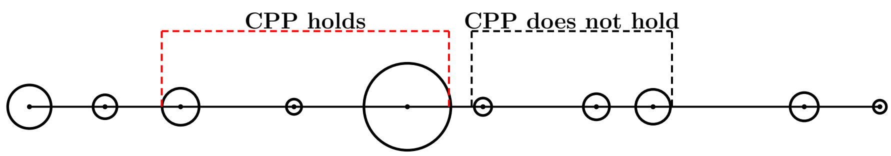
#	Possible Combination	Central Place Property
1		Yes
2		Yes
3		Yes
4		Yes
5		No
6		No

Note: Representation of possible combinations of three neighbouring urban areas on an island and the compliance with the central place property requirements. Each circular symbol signifies the size of the settlement, and the combinations are arranged in accordance with the requirements of the central place property. The third column indicates if the triplet meets the CPP requirement or not.

Once the algorithm checks all the possible triples on each island, it calculates the average share of triplets, satisfying the CPP. Fig. 3.3 plots Lakeba island on a one-dimensional geographical space for illustrative purposes. The size of each circle in Fig. 3.3 reflects the size of the detected urban areas, and the horizontal line represents the distance from the biggest urban area to the rest of the settlements.

It is straightforward to verify that the triplet marked by the red dashed line in Fig. 3.3 meets the requirement of CPP since it corresponds to #2 case in Table 3.1. At the same time, the combination captured by the black dashed line does not satisfy the CPP criteria as it is #6 scenario in Table 3.1. If

Figure 3.3: One-dimensional spatial distribution of urban areas on Lakeba island



Note: This figure plots the delineated urban areas on Lakeba island. For simplicity, the oval-shaped distribution of economic activity is transformed into a line. Each circle in the figure symbolizes the size of the urban area. The edge length from the biggest cluster to the rest represents the shortest distance predicted by Dijkstra Algorithm

the algorithm continues to check all the triplets on Lakeba island, the average CPP share would be 80%.

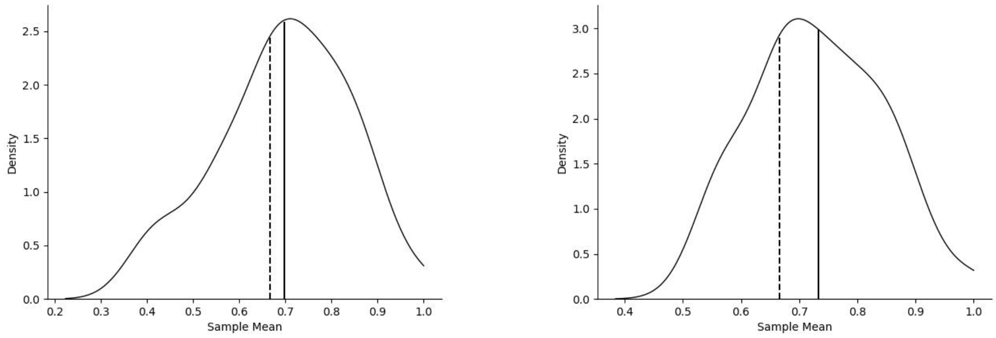
3.6 Results

The methodology outlined in the preceding section is applied to the final data to determine the average CPP share for each island. The results are depicted in Figure 3.4a, where Gaussian kernel density estimation is used to obtain a smooth distribution of the average values. The mean of the distribution, with a value of 0.7, is represented by the vertical solid line.

The distribution in Figure 3.4a displays a negative skewness, with a long tail extending towards lower values on the left-hand side. To more accurately reflect the central tendency and dispersion of the data, ten outliers were removed from the distribution. Figure 3.4b plots the resulting distribution without outliers. This change in the data resulted in a shift of the mean towards higher values on the right-hand side, with a value of 0.74. In both cases, the mean value of the distribution demonstrates that, on average, 70% (74%) of all possible triplets on each island exhibit the spatial pattern predicted by the central place property.

Having observed the size distribution of urban areas on each island in the

Figure 3.4: The distribution of the average CPP shares



Note: The figures plot the distribution of average CPP share. The left-hand side figure plots the results for the full data set. In the right-hand figure, ten outliers are dropped. A solid vertical line indicates the mean of the distribution. The dashed vertical line represents the mean of the hypothetical distribution obtained by randomizing the locations of the urban areas on each island.

data, this study proceeds by comparing the obtained average CPP share to the hypothetical mean of the CPP shares derived from randomizing the locations of the urban areas on each island. The comparison between the actual and hypothetical means evaluates the validity of the central place property in the observed data. If the actual mean of the CPP share is significantly higher than the hypothetical mean derived by randomizing the locations of settlements, it would suggest that the observed pattern of urban areas in the data conforms to the central place property.

Using Table 3.1 it is straightforward to show that the hypothetical mean of CPP share would converge to 2/3 if we repeat the randomized experiment many times. The one-sided z-test is used to compare the actual and hypothetical mean of the CPP shares. The results of this comparison are presented in a 3.2, which demonstrates that the actual mean of the CPP share is significantly higher (indicated by the lower p-value in the third column) than the hypothetical mean derived by randomizing the locations of urban areas on each island. As a result, this chapter argues that the observed spatial distribution of urban settlements in the data is not due to chance but is instead driven by the economic forces usually micro-founded in the theoretical literature.

Table 3.2: The results of the one-sided Z-test

Name	Statistics	p-value
Full Sample	0.26	0.048
w/t outliers	5.08	0.000

Note: The results of a one-sided Z-test for the full sample and the subset sample (without outliers) are presented in the table above. The statistics and p-value columns show the test statistic and the corresponding p-value for each sample. For the full sample (w/t outliers), the test statistic is 0.26 (5.08), and the p-value is 0.048 (0.00). This suggests that actual and hypothetical means are statistically significant at 5% level.

3.7 Conclusion

This chapter examines the validity of central place property (CPP), a key prediction of central place theory, according to which smaller cities can always be found between larger cities. The study uses global islands data to match the spatial distribution of economic activity with the assumption of the CPP that all economic activity takes place on a line or a circle. The urban areas on each island are detected using an unsupervised machine learning algorithm and building data from the Open Street Map. The results show that, on average, 70% of the neighbouring cities' size distribution follows the pattern predicted by the CPP. A simple one-tailed z-test confirms that the observed and counterfactual city size distributions, which are obtained by randomizing the location of urban areas on each island, are significantly different. Obtained results provide empirical evidence to support the theoretical prediction of central place property.

3.A Appendix

3.A.1 List of all islands in the data

Name	No. Buildings	Urban Area (thsd sq.m.)	No. Urban Areas
Almagro Island	1983	1930.0	14
Ambae	5000	43672.0	12
Babeldaob	990	21356.0	12
Banton Island	1421	3642.0	12
Pulau Bawean	7495	29234.0	13
Biliran	24798	106881.0	10
Bioko	3970	212245.0	14
Camiguin Island	49053	75923.0	5
Capul Island	1898	3226.0	12
Car Nicobar	669	1914.0	11
Catanduanes Island	39915	276025.0	9
Cebu	12417	15402.0	5
Cicia Island	747	1003.0	7
Dinagat Island	2828	14841.0	14
Efate	16801	145917.0	7
Epi	2568	20280.0	25
Ilha do Faial	13204	61645.0	4
Viti Levu	97522	1282602.0	7
Fogo	1548	30588.0	9
Grand Cayman	7239	56754.0	7
Ngazidja	39537	130260.0	13
Grenada	33969	86462.0	7
Hadseløya	645	5465.0	9
Hahajima	444	269.0	12
Iceland	94210	16608099.0	8
Maio	1371	9467.0	12
Iriomotejima Island	1879	5165.0	16
Isla de Providencia	1732	2998.0	7
Isola di Pantelleria	779	4415.0	9
Kaua?i	2683	58622.0	10
Ko Samui	5605	17894.0	13

Name	No. Buildings	Urban Area (thsd sq.m.)	No. Urban Areas
Koro Island	1622	4082.0	16
Kosrae Island	691	6304.0	16
Lakeba Island	1066	1669.0	10
Pulau Lembata	32686	144803.0	17
Ilha da Madeira	31414	277108.0	6
Mangareva	559	1098.0	12
Marinduque	1929	32172.0	13
Maripipi Island	872	1043.0	13
Mindoro	24008	1075215.0	15
Mo?orea	7474	15457.0	15
Pulau Morotai	12695	130965.0	26
Nauru	2175	3535.0	7
Naviti Island	866	928.0	14
Nevis	2278	16968.0	5
North Gigante Island	1233	818.0	6
Ovalau	1981	3656.0	19
Panaon Island	513	3234.0	17
Ilha do Pico	8060	51002.0	11
Pohnpei	3806	48872.0	8
Pulau Hiri	768	324.0	6
Pulau Kadatuang	1648	573.0	7
Pulau Manadotua	902	592.0	7
Pulau Manawoka	1202	391.0	8
Pulau Nusalaut	1645	1294.0	9
Pulau Palue	2547	3486.0	17
Pulau Pura	1652	1150.0	14
Rarotonga	4657	10091.0	9
Rimatara	263	345.0	8
Rishiri-to	4084	6327.0	12

Name	No. Buildings	Urban Area (thsd sq.m.)	No. Urban Areas
Rotuma	847	1748.0	18
Rurutu	733	1783.0	11
Saint Lucia	33311	156287.0	9
Samothraki	811	7522.0	12
Limbangcavayan Island	620	1856.0	8
São Tomé	6443	31489.0	11
Savai?i	16784	195478.0	9
Saint Kitts	8749	42662.0	7
Saint Vincent	27569	65182.0	9
Tablas Island	8154	101475.0	6
Tenerife	81801	589149.0	7
Ilha Terceira	17498	72208.0	10
Thasos	4937	15496.0	8
Pulau Tidore	12018	17160.0	11
Isla del Tigre	1261	1450.0	14
Tobago	1495	25398.0	12
Tonowas	786	2763.0	7
Tubuai	1097	3854.0	13
Tustna	1452	13157.0	7
Ua Pou	782	4189.0	6
Upolu	23436	246829.0	9
Weno	3265	5117.0	6
Wowoni	3298	5527.0	13
Yakushima	616	8306.0	10
Pulau Sorenarwa	8658	108481.0	10

3.A.2 Basic descriptives of the sample distribution

Statistics	Value
count	84.000000
mean	0.697550
std	0.143192
min	0.400000
25%	0.584034
50%	0.710084
75%	0.800000
max	1.000000

Concluding remarks

This dissertation contributes to the literature on international trade by investigating the effects of globalisation on firm behaviour and regional production fragmentation. The first chapter develops a model that shows how firms compete for workers by offering them higher wages and investing in the quality of workplace amenities. The chapter demonstrates that there are non-monetary welfare gains from globalisation, and welfare metrics which exclusively focus on real income gains might underestimate the gains from globalisation. The second chapter examines the impact of trade liberalisation on regional production fragmentation. It provides empirical evidence that regions within the EU facing larger tariff cuts followed by the 2004 EU enlargement have significantly increased trade along the value chain. The third chapter of the dissertation contributes to the economic geography literature. In particular, it examines the validity of the central place theory. By collecting geospatial data on volcanic islands, the third chapter tests central place property, which postulates that smaller cities can always be found between larger cities. Obtained results suggest that the city size distribution in the observed data follows the spatial pattern predicted by the CPP.

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